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ABSTRACT

These five volumes of student materials for a secondary/postsecondary level course in radiology technology comprise one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The purpose stated for the course is to provide the theory portion of technician advanced training in radiology. The course contains useful information for a beginning student in radiology but is intended for advanced, on-the-job learning for students with prior training in the field. Each volume contains several chapters consisting of several learning objectives with text, text exercises, and an answer key to exercises. A volume review exercise with questions keyed to the text is provided, but no answers are available. The volumes cover these topics: radiographic fundamentals, osteology and positioning, special techniques (mammography, obstetrical radiography, tomography, and stereoscopic radiography), special procedures (contrast studies of the digestive, urogenital, respiratory, cardiovascular, and nervous systems), and general information and administration (muscular, integumentary, and endocrine systems; field radiography; and radiation therapy). (YLB)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

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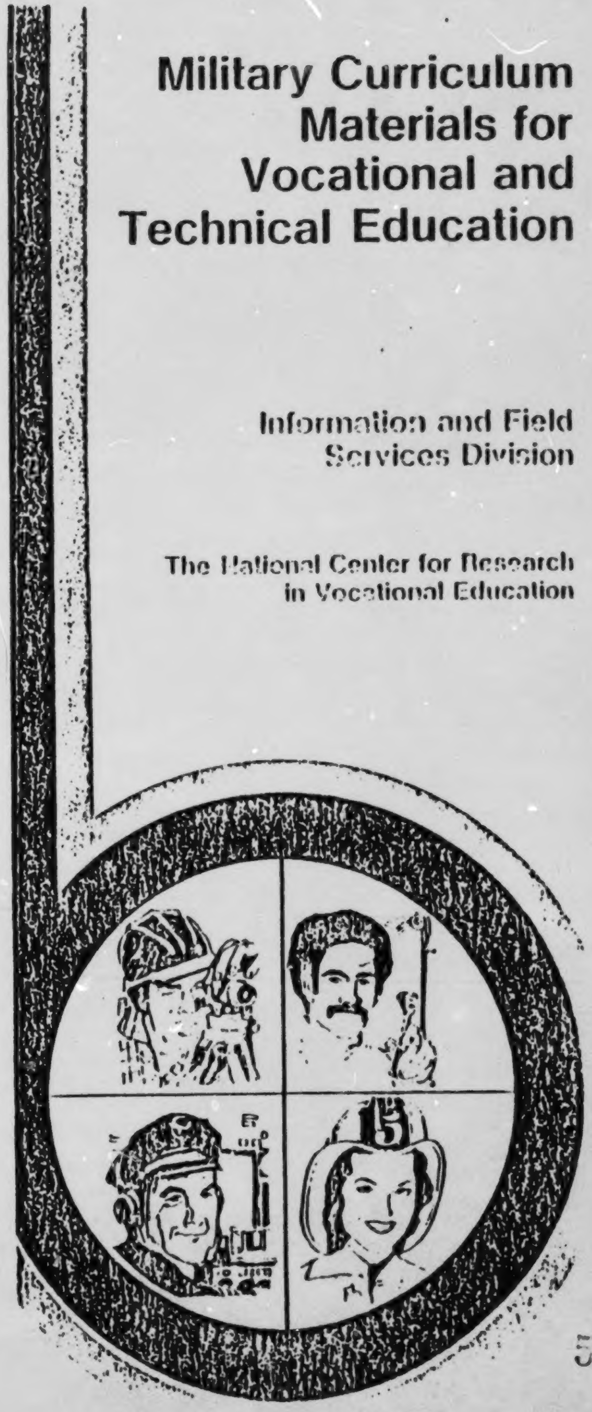

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

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RADIOLOGY TECHNICIAN

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RADIOLOGY TECHNICIAN

Correspondence Course

10-5

Developed by:

United States Air Force

Development and Review Dates:

Unknown

Occupational Area:

Health

Cost:

Print Pages:

521

Availability:

Military Curriculum Project, The Center
for Vocational Education, 1960 Kenny
Rd., Columbus, OH 43210

Suggested Background:

Previous experience in biology, physiology, and radiology

Target Audiences:

Grades 12-14

Organization of Materials:

Criterion objectives, text, exercises, answers, volume review exercises

Type of Instruction:

Individualized, self-paced

Type of Materials:		No. of Pages:	Average Completion Time:
Volume 1 —	*Radiographic Fundamentals*	119	Flexible
	Volume Review Exercise	14	
Volume 2 —	*Osteology and Positioning*	86	Flexible
	Volume Review Exercise	12	
Volume 3 —	*Special Techniques*	88	Flexible
	Volume Review Exercises	12	
Volume 4 —	*Special Procedures*	104	Flexible
	Volume Review Exercise	13	
Volume 5 —	*General Information and Administration*	40	Flexible
	Volume Review Exercise	9	

Supplementary Materials Required:

None

Course Description

This course was designed to provide the theory portion of Technician (advanced) training in radiology. It should accompany laboratory work or on-the-job assignments. This course follows the Apprentice (semi-skilled) and Specialist (skilled) levels in this career but contains review materials from both. The job duties outlined for this position are:

- Operates X-ray equipment
- Assists in fluoroscopic examinations
- Assists radiologist in treatment of disease by radiation therapy
- Enforces health-protective measures
- Supervises radiology

The course is divided into five volumes each containing several chapters. Each chapter consists of several learning objectives with text, review exercises and answers.

Volume 1 — *Radiographic Fundamentals* discusses fundamentals of X-ray production; the primary beam; exposure devices; film, film holders, and darkrooms; control of film quality; and environmental safety.

Volume 2 — *Osteology and Positioning* describes the osteology of the extremities, vertebral column, ribs, sternum, skull, facial bones, and paranasal sinuses.

Volume 3 — *Special Techniques* covers mammography, obstetrical radiography, tomography, stereoscopic radiography, localization of foreign bodies, scanography and arthrography, bedside and surgical radiography, and film duplication and subtraction.

Volume 4 — *Special Procedures* discusses contrast studies of the digestive, urogenital systems, respiratory systems, cardiovascular systems, and the nervous system.

Volume 5 — *General Information and Administration* covers the muscular, integumentary, and endocrine systems; field radiography; and radiation therapy. The chapter on the radiology career field, and the chapter on supervision, training, supply, and general radiology administration were deleted because they referred to specific military procedures and organization.

This course contains useful information for a beginning student in radiology, but was designed for advanced on-the-job learning for students who have completed some prior training in the field. The course is designed for student self-study with criterion objectives, coded text, and criterion tests and answers. The volume review exercises are keyed to the objectives but no answers are provided.

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CDC 90370

RADIOLOGY TECHNICIAN

(AFSC 90370)

Volume 1

Radiographic Fundamentals

Extension Course Institute
Air University

10-5

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PREPARED BY
SCHOOL OF HEALTH CARE SCIENCES, USAF (ATC)
SHEPPARD AIR FORCE BASE, TEXAS

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

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Preface

IN THE VERY early days of radiology, all of the mechanical work was done by the physician who owned the equipment. He positioned the patient, operated the X-ray generator, made the exposures, and processed the photographic plates. Naturally, this operation restricted the number of patients he could examine in a day's time. One enterprising physician reasoned that if he could train a layman to do the mechanical work, he would be free to handle the purely professional work of the science. He hired a man—the first technician—and taught him how to operate the generator and process the films. Unfortunately, because of a lack of information on the subject, he neglected to train the man in the basic fundamentals of the science. Such primary concepts as the theory of X-ray production, beam restriction, and protection against ionizing radiation were not include in the "technician's" training. This exclusion of now vital fundamental information had dire results. Both technician and radiologist, ignorant of the consequences, worked in the primary beam, and consequently, were overexposed—some to the point that the radiation crippled them.

Radiology today has evolved into a highly technical science. Because of this, knowledge of the fundamentals of our field becomes more and more important to you. Without a good fundamental background, you cannot understand and apply the new concepts and therefore provide the best patient care.

This volume of the CDC is devoted to the basic fundamentals of radiology. Some of the information may seem familiar to you since we have included selected review material from the Phase I and the Phase II Air Force training programs. You will also discover throughout this volume and the complete CDC many references to quality control, with which you will become more and more involved throughout your career.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to School of Health Care Sciences/MST, Sheppard AFB TX 76311. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 36 hours (12 points).

Material in this volume is technically accurate, adequate, and current as of January 1975.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Fundamentals of X-ray Production

IN ORDER TO BECOME a competent radiologic technologist you must understand the equipment with which you are working. It is true that you can produce a radiograph, perhaps an excellent one, without understanding the operation of the X-ray machine. But what action would you take, for example, if you have occasion to make several high-load exposures in rapid succession. Could you determine if the exposures exceed the maximum limits of your X-ray tube? Would you even consider checking the tube rating chart at all? These are some of the things that separate the radiologic technologist from someone you no doubt have heard referred to as a "button pusher."

You are not expected to learn all the complexities of X-ray machine operation. On the contrary, most of this chapter is limited to factors that affect either the speed or the number of electrons that interact with the tube target to produce X-radiation. Keep in mind as you study this chapter that factors which affect the electron ultimately affect the quality or quantity (photon energy and number of photons per unit area) of the X-radiation.

1-1. Fundamentals of Electricity

All the effects of electricity can be explained by assuming the existence of a minute particle called the electron. Using the electron theory, scientists are able to make discoveries and predictions that seemed impossible only a few years ago. The electron is not only the basis of design for all electrical equipment; it is also directly connected to the production of X-radiation, as mentioned in the introduction to this chapter. We begin our study of the electron with a review of electrical current.

001. Define electrical current and list three factors that influence electron movement in a conductor.

Basic Theory of Electrical Current. The flow or movement of electrons through a conductor constitutes an electrical current. What causes electrons to flow through a conductor? Refer to figure 1-1 where two containers of water are connected by a pipe. Obviously the water will flow from left to right until we have the same amount of water in both containers. If we compare the drops of water with electrons, then we could say that the container on the left has a surplus of electrons, and the container on the right has a shortage of electrons. Since electrons have a negative charge, we could also say that the container on the left is negative and the one on the right is positive. This difference between electrostatic charges is an important factor that affects the movement of electrons in a conductor.

Whenever we have opposite charges, we also have a *difference in potential*, and it is this difference in potential that is required to produce electron flow in a conductor. Again refer to figure 1-1. Once we have the same water level in both containers, water will stop flowing because there is no longer a difference in potential—or, in the case of electrons, we could say we have *like charges*.

The flow of water from one container to the other in figure 1-1 is also influenced by the characteristics of the pipe connecting the two. This is easy to understand if you imagine how replacing the pipe with one having a smaller diameter would slow the movement of water from one container to another. In case of an electrical current, electron flow is likewise affected by the amount of resistance of the conductor or of other devices present in the circuit.

Exercises (001):

1. Define electrical current.

short one, assuming that the two conductors are otherwise equal. In other words, the resistance of a conductor is proportional to its length.

Another factor affecting conductor resistance is its *cross-sectional* area. The greater the cross-sectional area, the lower the resistance; the smaller the cross-sectional area, the greater the resistance. A large cross-sectional area provides a larger space through which the electrons move; consequently, fewer electron collisions result. If we compare the resistance of two conductors, one with twice the cross-sectional area of the other, the larger conductor offers only one-fourth as much resistance as does the smaller one.

The final factor affecting the resistance of a conductor is its *temperature*. For *most* materials, the hotter the material, the more resistance it offers to an electrical current; and the colder the material, the less resistance it offers to the electrical current. This effect comes about because a change in the temperature of a material changes its molecular activity. The effect of temperature upon resistance is the least important of the four factors—material, length, cross-sectional area, and temperature—that control resistance.

Exercises (005):

1. Assuming all other factors are equal, do two current-carrying wires made of different materials offer the same resistance to current flow?

2. Assuming all other factors are equal, does copper offer more or less resistance than iron? Does aluminum offer more or less resistance than copper?

3. If a 3-foot conductor offers 6 Ω resistance, how much resistance does a 1-foot conductor offer, if all other factors are equal?

4. Why is the resistance of a conductor influenced by conductor length?

5. If a conductor's resistance is 2 Ω, how much resistance is present in a conductor with twice the cross-sectional area if all other factors are equal?

6. Does conductor temperature affect its resistance? If so, does a high temperature increase or decrease resistance?

7. Of the factors discussed that affect conductor resistance, which one is least important?

006. Using the formulas derived from Ohm's law, find the following circuit values: (1) current if voltage and resistance are given, (2) resistance if voltage and current are given, and (3) voltage if current and resistance are given.

Ohm's Law. To this point, our discussions of current, voltage, and resistance have mostly dealt with the relative values of those elements. Now, let's see how we can determine the specific values of any one of the three elements when we know what the other two values are.

The relationships between current, voltage, and resistance are expressed in Ohm's law. The law states: "In a DC circuit, current varies directly with the voltage and inversely with the resistance." If we know two of the three values, we can, by using the formulas derived from Ohm's law, determine the other value. The formulas are as follows:

Current: $I = \frac{E}{R}$

Resistance: $R = \frac{E}{I}$

Voltage: $E = I \times R$

An easy way to remember these formulas is by the use of the chart in figure 1-2. To use these formulas, cover the letter symbol for the value you are trying to determine. For instance, if you cover up the *E*, all you have left is $I \times R$. Therefore, in order to find the voltage, your formula is $E = I \times R$. Now, if you want to solve for current, you cover up *I*. This will leave you with $\frac{E}{R}$. There fore, if you want to calculate the current, your formula would be $I = \frac{E}{R}$. If you need the formula for resistance, just cover up the *R* and you will get the formula $R = \frac{E}{I}$. Now, let's see how Ohm's law is applied to a simple electrical circuit.

If you look at the circuit in figure 1-3, you will see that we have a battery, which we shall assume is providing 6 volts. The lamp has a resistance of 2 ohms when the switch is closed; and the problem is to find the current. Since we are looking for current, we use the formula $I = \frac{E}{R}$. When we substitute the two known values for E and R, we have $\frac{6}{2}$. Therefore, $I = \frac{6}{2}$; or, $I = 3$ amps. Even though we now know all the values in this circuit, let's use the formula for practice to prove each value. First, let's solve the R, the formula for which is $R = \frac{E}{I}$. Substituting values, we have $R = \frac{6}{3}$; or, $R = 2$ ohms. To solve for E, the formula is $E = I \times R$. Therefore, $E = 3 \times 2$; or, $E = 6$ volts.

Exercises (006):

1. What is the resistance in a circuit if the voltage is 110 volts and the current is 5 amperes?

2. What is the voltage in a circuit if the current is 2 amperes and the resistance is 55 ohms?

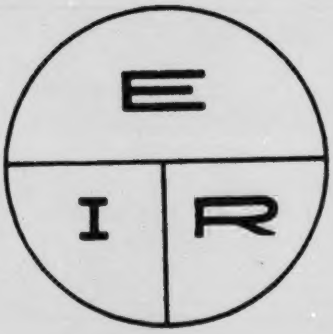

Figure 1-2. The Ohm's law chart.

3. What is the current in a circuit if the voltage is 12 volts and the resistance is 4 ohms?

007. Given a schematic of a circuit showing various component symbols, identify the symbols shown.

Symbols of Circuit Components. For simplicity and to save space, symbols of circuit components are used rather than pictures. While it is not necessary for you to identify all component symbols, you will need to identify some of the most common symbols used throughout this chapter. In

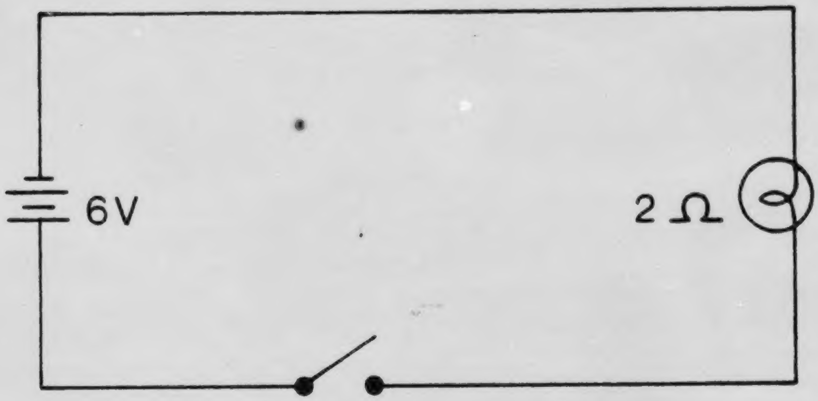

Figure 1-3. A simple DC circuit.

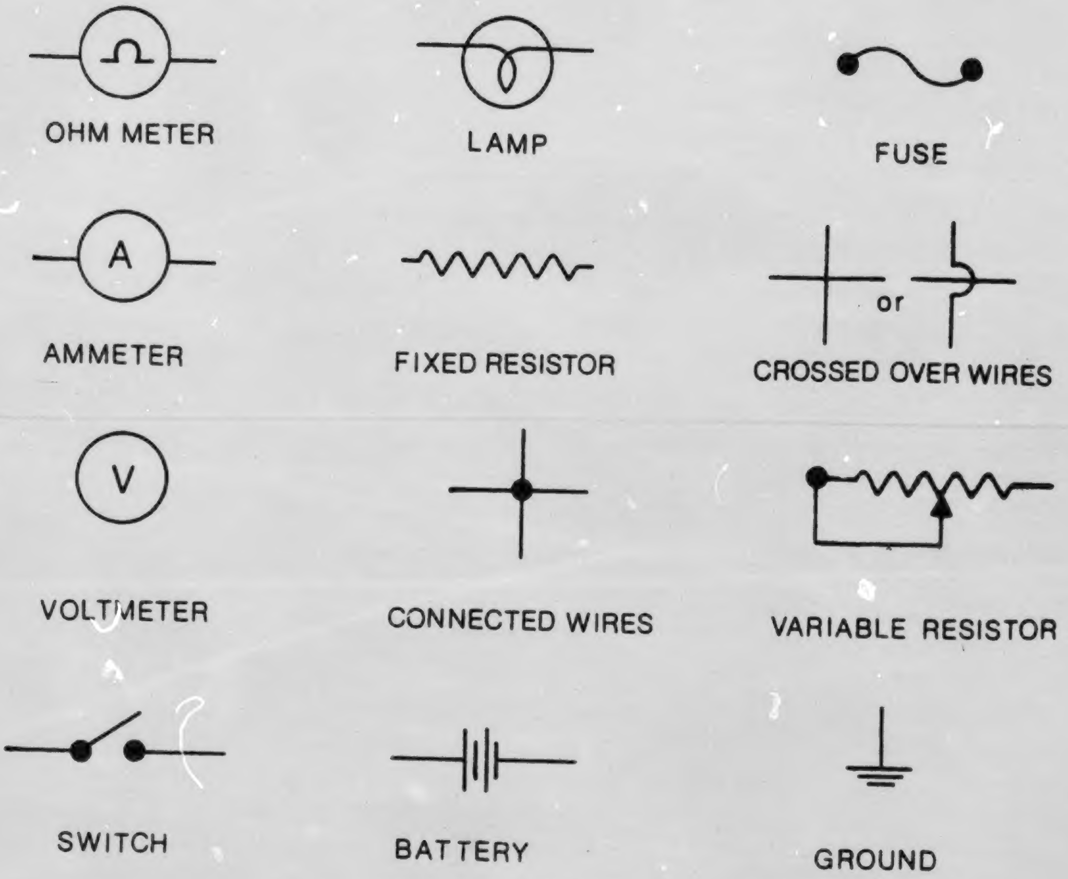

Figure 1-4. Some common circuit component symbols.

addition, this knowledge will aid you considerably in interpreting other technical literature. Figure 1-4 shows the common circuit symbols you should know. (NOTE: When a battery symbol is used, the battery voltage is sometimes written alongside the symbol.)

Exercises (007):

Figure 1-5 is a circuit schematic showing 11 commonly used component symbols. Opposite the appropriate numbers below, write the name of each component symbolized in figure 1-5.

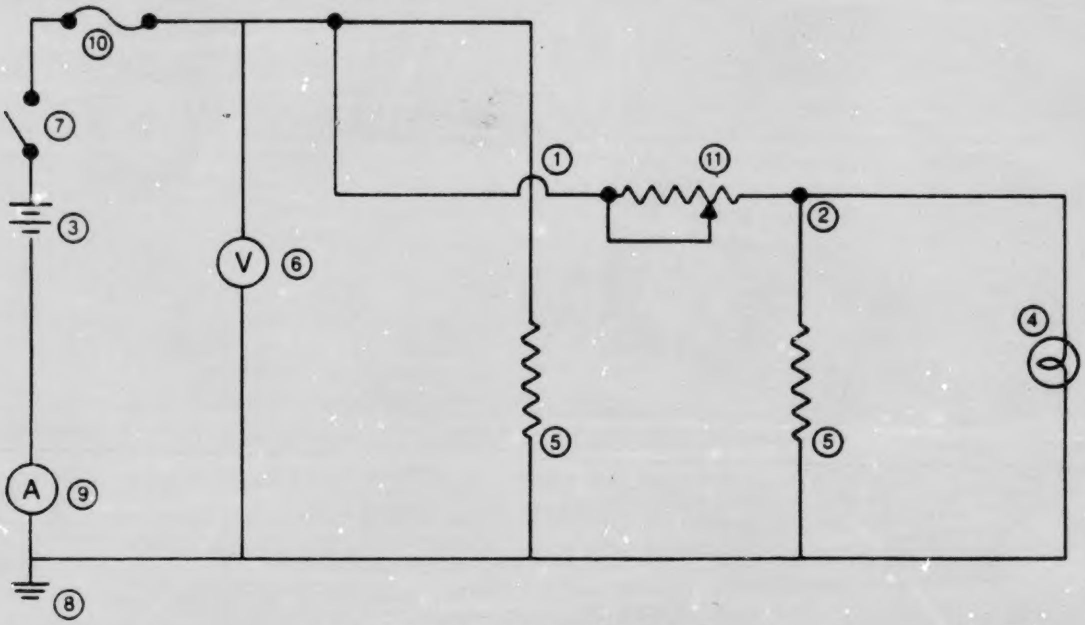

Figure 1-5. Objective 007, exercises 1 through 11.

1.
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3.
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8.
9.
10.
11.

008. Given a schematic of a series circuit, including total voltage and individual resistor values, find the current at various points in the circuit, the total resistance of the circuit, and the voltage drop across each resistor.

Basic Electrical Circuits. Electrical circuits are classified according to the way their components are arranged or connected. The three types of circuits are *series*, *parallel*, and *series-parallel*. See figure 1-6.

Series circuit. A series circuit is one in which the components are connected end to end and there is only one path for the current. See figure 1-7,A, which shows three electrical devices connected in series.

Now, let's discuss the behavior of current, resistance, and voltage in a series circuit. Current is the simplest, so let's consider it first, with the aid of figure 1-7,B. If we close the switch, completing the circuit, the three ammeters should show the amount of current at various points in the circuit. All the ammeters should read the same amount of current. This is the first important thing to remember about a series circuit: *Current is the same at all points in a series circuit.* This is sometimes expressed in formula form as:

$$I_t = I_1 = I_2 \ldots$$

Total Current	equals	Current through R_1	equals	Current through R_2

It doesn't matter how many resistors you have. If there were five resistors in the circuit, the formula would be:

$$I_t = I_1 = I_2 = I_3 = I_4 = I_5$$

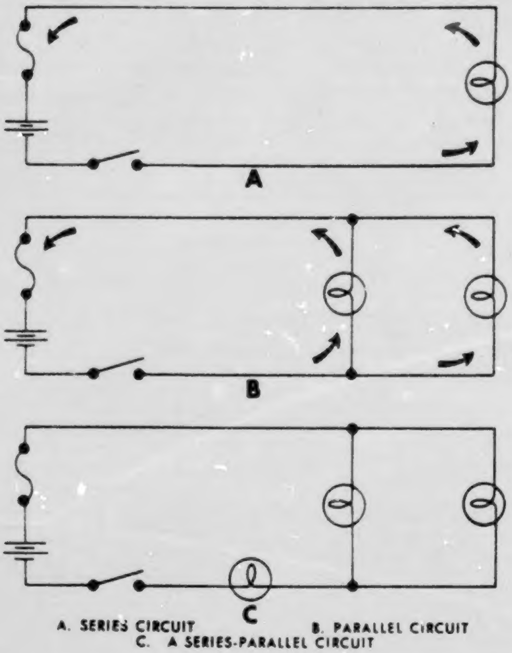

Figure 1-6. Representative simple circuits.

Notice that we haven't said how much current there is. We have said merely that whatever the current is, it's the same everywhere in the circuit.

The total resistance in a series circuit is equal to the total of the separate resistors. No matter how many resistors are in a series circuit, they all have to be added to find the total resistance. This rule can be expressed as the following formula:

$$R_t = R_1 + R_2 + R_3 + R_4 \ldots$$

In a circuit, the voltage drop across a resistor is the voltage required to force the current through the resistor. *The total of the voltage drops across all the resistors in a series circuit equals the voltage applied to the circuit.* To determine the voltage drop across each resistor, use Ohm's law ($E = I \times R$). For example, if there are two resistors in a 12-volt circuit with values of 2 Ω and 4 Ω, the voltage drop across each resistor is 4 volts and 8 volts respectively. Of course, you must first determine the current in the circuit by using Ohm's law before you can determine the voltage drop. In case of our example cited above, the current in the circuit is 2 A since $I = \frac{E}{R}$ ($E = 12\ V$ and $R_t = 6\ \Omega$). Then to find the voltage drop across the 2 Ω resistor, use the formula $E = I \times R$. Since $I = 2\ A$ and $R = 2\ \Omega$, the voltage drop is 4 volts. The voltage drop across the 4 Ω resistor is 8 volts, since $I = 2\ A$ and $R = 4\ \Omega$.

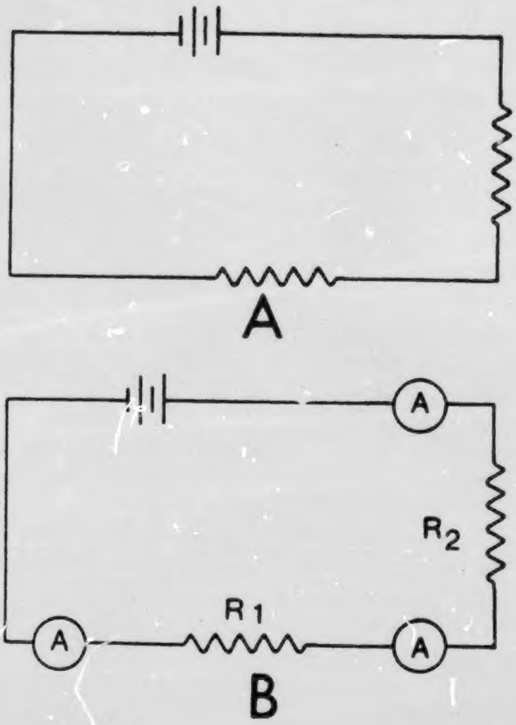

Figure 1-7. Representative series circuits.

Exercises (008):

Using figure 1-8, complete the following exercises.

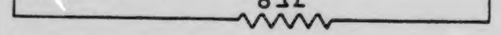

Figure 1-8. Objective 008, exercises 1 through 3.

1. What is the current between R_3 and R_2? Between R_2 and R_1? Between R_1 and the battery?

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2. What is the total resistance in the circuit?

3. What is the voltage drop across R_1? Across R_2? Across R_3?

009. Given a schematic of a parallel circuit, including the total voltage and individual resistance values, find the voltage at various points within the circuit, the current through each resistor, and the total resistance of the circuit.

Parallel circuit. It is often necessary to connect electrical devices in a circuit so that the total voltage is applied across each device. A circuit in which two or more devices are connected across a common power source is called a parallel circuit. Let's examine the behavior of voltage, current, and resistance in a parallel circuit.

Note in figure 1-9 that points a, b, c, and d are connected and are one point electrically. Similarly, points e, f, g, and h comprise another electrical point. Since the applied voltage appears between points a and e, the same voltage appears between points b and f and between points c and g, as well as between points d and h. So it can be said that *when resistors are connected in parallel across a voltage source, each resistor has the same voltage applied to it, although the currents may differ depending upon the values of resistance.* The voltage in a parallel circuit may, therefore, be expressed mathematically as follows:

$$E_t = E_1 = E_2 = E_3$$

where E_t is the applied voltage, E_1 is the voltage across R_1, E_2 across R_2, and E_3 across R_3.

The current, on the other hand, divides among the various branches in a parallel circuit in a manner depending upon the resistance of each branch. In a parallel circuit, branches with low resistance draw more current than branches with high resistance. Therefore, the current in the circuit may be expressed mathematically as follows:

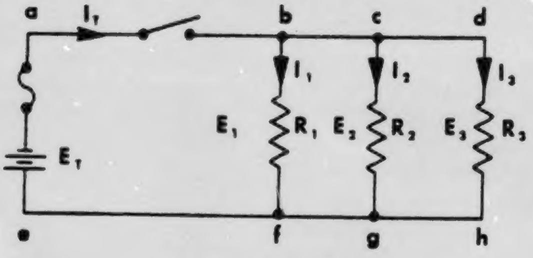


Figure 1-9. A parallel DC circuit.

$$I_t = I_1 + I_2 + I_3$$

where I_t is the total current and I_1, I_2, and I_3 are the currents through R_1, R_2, and R_3 respectively.

The total resistance in a parallel circuit is always less than the lowest resistance in the circuit. There are several methods to compute the total resistance; however, the reciprocal method will be the only one discussed here. As a rule, we can say that the effective resistance of parallel resistors is equal to the reciprocal of the sum of the reciprocals. Although this may sound complicated, it is not. Let's look at the formula:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Suppose the values of the resistors above are R_1 1 ohm, R_2 2 ohms, and R_3 2 ohms. Substituting the resistance values in the formula we find:

$$\frac{1}{R_t} = \frac{1}{1} + \frac{1}{2} + \frac{1}{2}$$

$$\frac{1}{R_t} = \frac{2}{2} + \frac{1}{2} + \frac{1}{2}$$

$$\frac{1}{R_t} = \frac{4}{2}$$

$$\frac{1}{R_t} = 2$$

$$\frac{1}{R_t} = \frac{2}{1}$$

$$2\ R_t = 1 \text{ or } R_t = 0.5$$

Therefore, the total resistance in this parallel circuit would be 0.5 ohm.

Exercises (009):

Using figure 1-10, complete the following exercises.

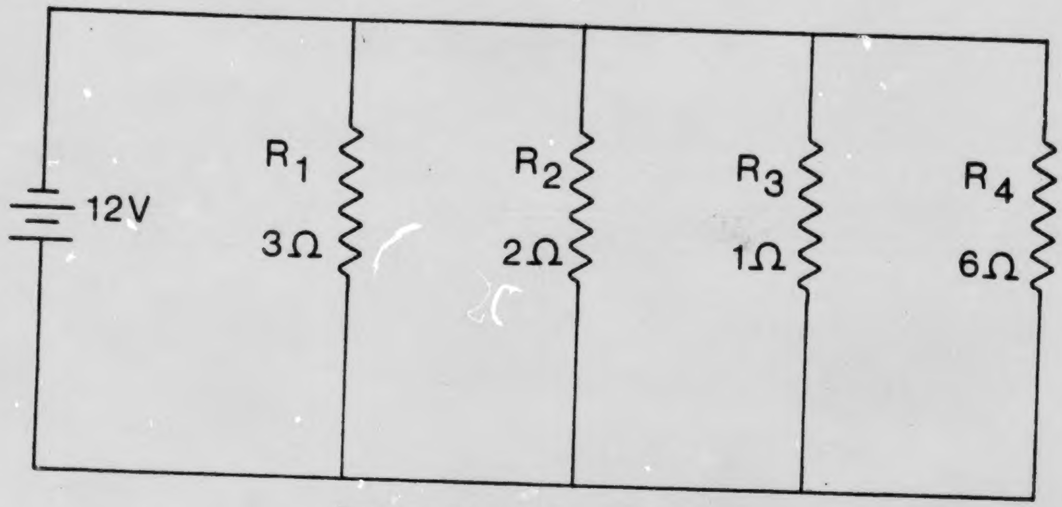


Figure 1-10. Objective 009, exercises 1 through 4.

1. What is the voltage across R_1? Across R_4?

2. What is the current through R_1? Through R_2? Through R_3? Through R_4?

3. What is the total current in the circuit?

4. What is the total resistance in the circuit?

010. Given a schematic of a series-parallel, find the total resistance in the circuit.

Series-parallel (compound) circuit. A series-parallel circuit consists of two or more parallel resistors connected in series with one or more resistors. Let's look at such a circuit and see the relationships between current, voltage, and resistance.

The easiest way to find the different values is to redraw the circuit into a series circuit and find the values just as you would any other series circuit. Figure 1-11,A, shows a series-parallel circuit with three resistors. The first thing you should do is to find the equivalent resistance of the parallel resistors (R_1 and R_2) by using the reciprocal method. Then redraw the circuit into a series circuit (fig. 1-11,B) to include R_3 and another resistor R_4, which represent the equivalent resistance of R_1 and R_2. In this case the resistance of R_4 is 1 Ω.

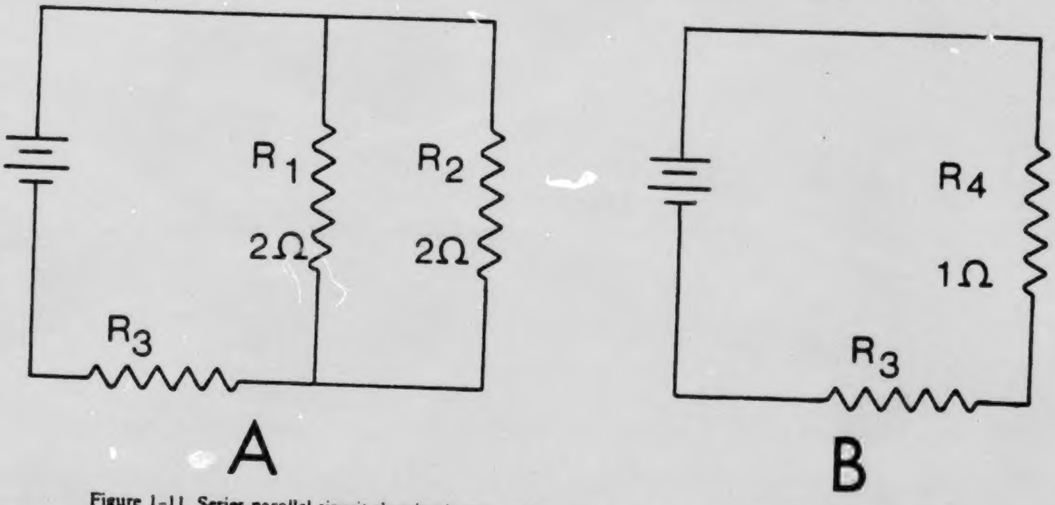


Figure 1-11. Series-parallel circuit showing how to redraw the circuit into a series circuit to find the total resistance.

Exercise (010):

1. Figure 1-12 shows a series-parallel circuit. What is the total resistance of the circuit?

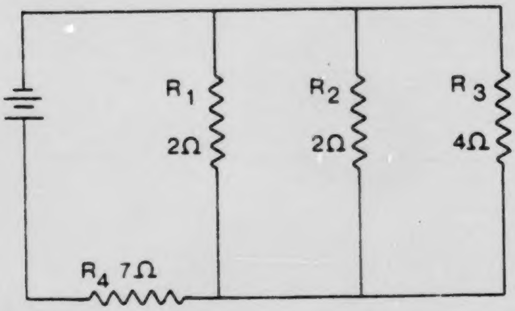


Figure 1-12. Objective 010, exercise 1.

011. Define magnetism, answer key questions about a magnetic field, and state the laws of magnetic attraction and repulsion.

Magnetism. Since there is a definite relationship between electricity and magnetism, a study of electricity must include a discussion of magnetism. It is of special importance to you because magnetism is used in many aspects of X-ray machine and other related equipment operation. Magnetism can be defined as a force which attracts iron, steel, or other magnetic substances.

Magnetic field. A magnet, regardless of shape or size, has a north pole (N) and a south pole (S), as shown in figure 1-13. Also shown is an invisible magnetic field, which is present around and inside a magnet. This magentic field can be demonstrated by palcing a piece of paper over a bar magnet and sprinkling iron filings on the paper. Tap the paper gently, and the iron filings will arrange themselves to coincide with the magnetic field (see fig. 1-14).

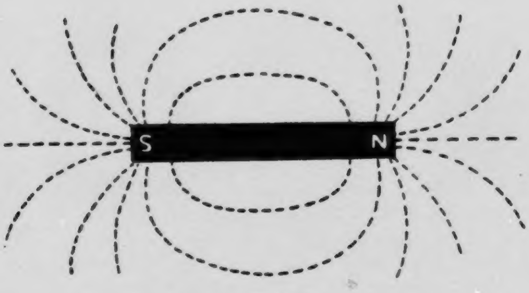


Figure 1-13. Magnetic poles and magnetic field.

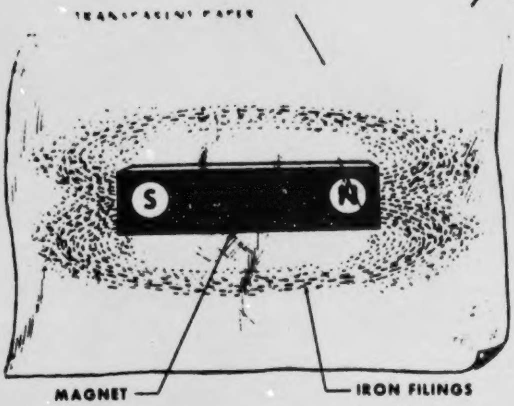


Figure 1-14. Demonstration of the magnetic field.

The magnetic field is made up of *lines of force,* also called *flux lines.* These lines of force travel from the north pole to the south pole outside the magnet and from the south pole to the north pole within the magnet. The strength of a magnetic field depends upon the number of lines of force per unit area; the more concentrated the lines, the stronger the field. These lines are more concentrated at the poles.

Laws of attraction and repulsion. There are two laws that describe the attraction and repulsion of magnetic poles: (1) like magnetic poles repel each other, and (2) unlike magnetic poles attract each other.

Exercises (011):

1. Define magnetism.

2. Where, in relation to the magnet itself, is the magnetic field located?

3. In what directions do the lines of force travel?

4. What determines the strength of a magnetic field?

5. State the laws of magnetic attraction and repulsion.

012. Differentiate between magnetic and nonmagnetic substances; and given statements

pertaining to magnetic dipoles and the relationship between magnetic dipoles and the magnetic field, indicate which are true and which are false.

Magnetic and nonmagnetic substances. All matter is affected to some extent by a magnetic field. Substances strongly attracted by a magnetic field are called "magnetic substances," and substances not noticeably affected by a magnetic field are generally classified as "nonmagnetic substances." Iron and steel are examples of strongly magnetic materials, while wood, copper, and glass are nonmagnetic.

Magnetic materials consist of millions of tiny elementary magnets, called *magnetic dipoles* or *magentic domains*, which are molecular or atomic in size. When these dipoles are arranged at random in an unmagnetized bar of iron or steel (fig. 1-15,A), the cumulative magnetic strength of the dipoles is neutralized. If a magnetizing force is applied to the iron bar, the dipoles become aligned so that all their north poles point in one direction and all their south poles point in the opposite direction (fig. 1-15,B). With the dipoles aligned in this manner, their magnetic strengths are combined, and lines of force, or a magnetic field, results. The bar is then magnetized. The direction of travel of the lines of force in and around this magnet is established, based upon the alignment of the poles of the magnetic dipoles. See figure 1-15,C.

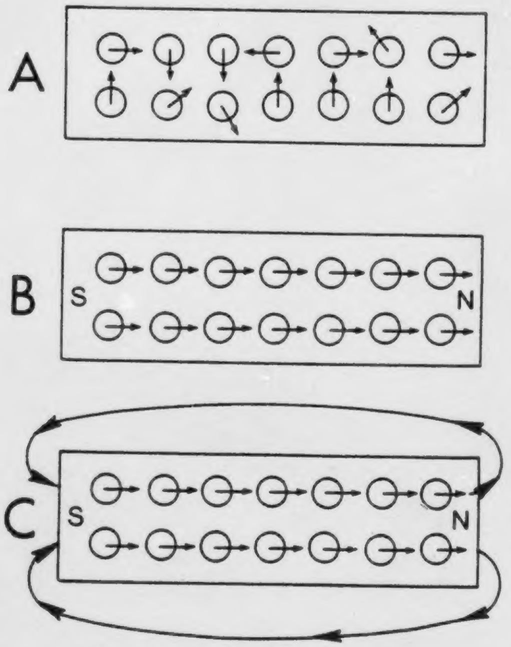


Figure 1-15. Iron bar showing arrangement of magnetic dipoles before and after application of a magnetizing force. Also shown is the relationship between dipole alignment and direction of lines of force.

Exercises (012):

1. What is the difference between magnetic and nonmagnetic substances?

2. Give two examples of a magnetic material and three examples of a nonmagnetic material.

Indicate whether the following statements are true or false.

T F 3. In an unmagnetized magnetic material, the magnetic dipoles are arranged in a random pattern.

T F 4. Uniform alignment of magnetic dipoles results in an external magnetic field.

T F 5. Direction of travel of lines of force is determined by the direction of alignment of the magnetic dipoles.

013. Show the relationship between a current-carrying conductor and the electromagnetic field around the conductor.

Electromagnetism. If a current is passed through a wire conductor, a magnetic field similar to the magnetic field of a bar magnet is created around the conductor. This magnetic field is sometimes called an electromagnetic field.

Relationships between conductors and magnetic fields. The lines of force around a straight, current-carrying conductor are circular and at right angles to the direction of current flow (see fig. 1-16). The magnetic field in this case does not have a north or south pole.

If a current-carrying conductor is formed into a loop or coil, as illustrated in figure 1-17, the lines of force pass through the inside of the coil, as shown. As a result, a north pole is created on one end of the

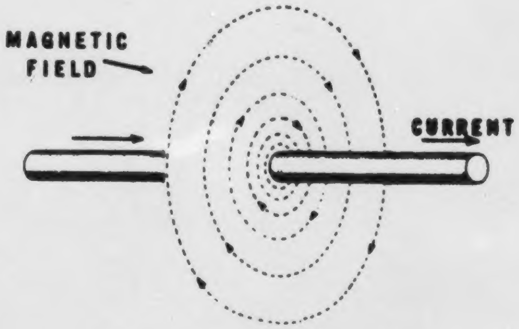


Figure 1-16. Electromagnetic field around a straight current carrying conductor.

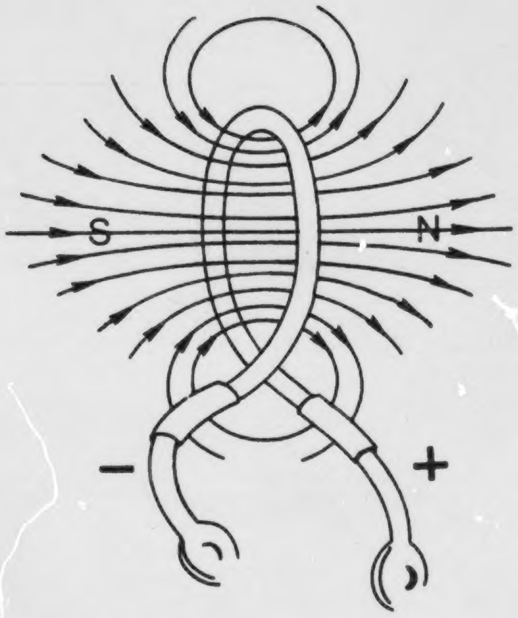


Figure 1-17. Electromagnetic field around a single wire conductor loop.

loop and a south pole on the other. The direction of the lines of force is the same as that of a bar magnet with the inside of the coil representing the magnetic bar.

If the wire conductor is formed into many loops, as shown in figure 1-18, the lines of force around the individual loops combine to form a larger and stronger magnetic field. A north and a south pole are then established at opposite ends of the coil.

The direction of the lines of force around a conductor depends upon the direction of current flow and can be determined by using the left-hand rule, as shown in figure 1-19. If the left hand is placed around a conductor so that the thumb points in the direction of current flow, the lines of force travel in the same direction as the fingers. Refer *again to figure 1-18 and imagine placing your left* hand at various points in the coil, and you can see the validity of this rule.

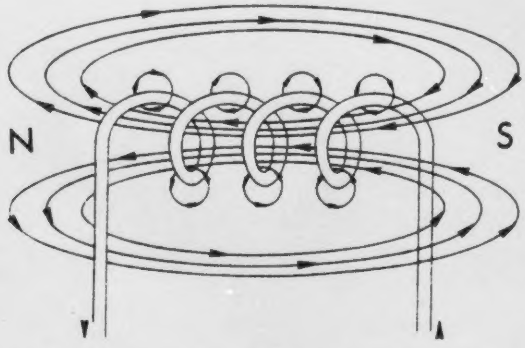


Figure 1-18. Electromagnetic field around a wire conductor formed into several loops.

Exercises (013):

1. What condition must exist for a magnetic field to be created around a wire conductor?

2. Does polarity exist in the magnetic field of a straight conductor? If not, what can be done to create a north and a south pole within the magnetic field?

3. Where are the north and south poles located with respect to a current-carrying coil?

4. What determines the direction of travel of the magnetic lines of force around a conductor?

5. Explain the left-hand rule for determining the direction of travel of the lines of force around a conductor?

014. List the three factors influencing the magnetic strength of a coil, and in each case explain the relationship between the influential factor and the magnetic strength.

Factors influencing the magnetic strength of a coil. When a conductor is wound into a coil, the lines of force around each loop combine with those from other loops to form one magnetic field. It follows that the more loops or turns per unit area—or we can say the more turns per inch—the stronger the field.

As the current through the conductor increases, so does the number of lines of force around the conductor; consequently, a higher current also produces a stronger magnetic field.

Another factor that influences the magnetic strength of a coil is the insertion of an iron core in the center of the coil. The iron core affects the magnetic strength for two reasons: (1) the core itself becomes magnetizied, and its magnetic strength is added to that of the coil and (2) the core provides an easier pathway for the lines of force to travel; thus the lines of force concentrate themselves within the core. Soft iron is usually used as core material because it has a high permeability, which

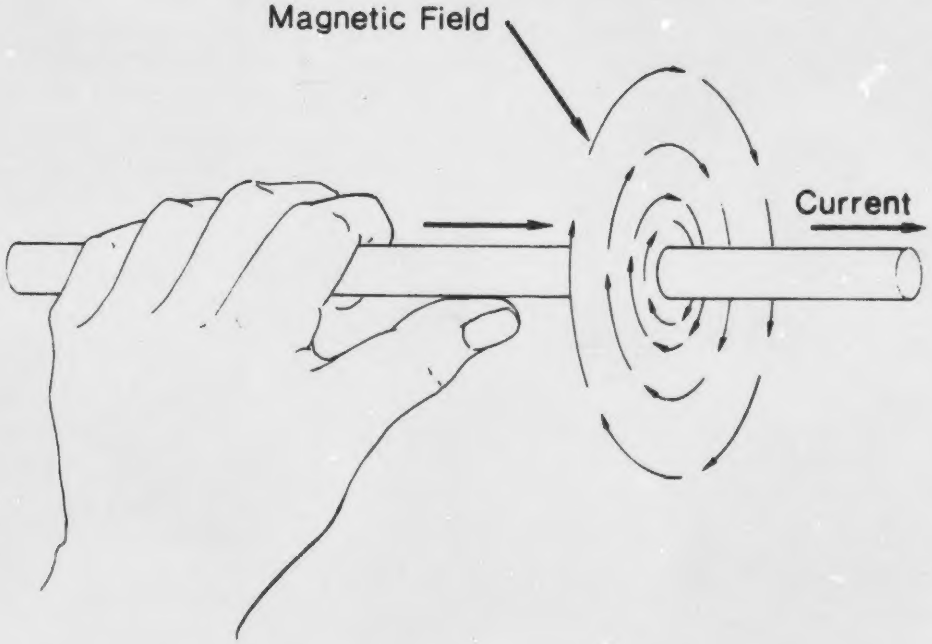


Figure 1-19. Left-hand rule for determining the direction of lines of force around a conductor.

determines the ability of a material to conduct or concentrate lines of force. (NOTE: Soft iron also has low retentivity. Retentivity is a characteristic that determines the ability of a substance to remain magnetized after the current is turned off. Low retentivity is necessary for precise control of an electromagnetic field.)

Exercises (014):

In exercises 1 through 3 below, list three factors influencing the magnetic strength of a coil. After each factor, explain how it affects the magnetic strength.

1.

2.

3.

015. Given statements pertaining to the centering effect of an iron core within a current-carrying coil and its applications, indicate which are true and which are false. If you indicate "false," explain your answer.

Iron core centering effect. The iron core we have discussed is useful in the construction of various electrical devices. Its usefulness is attributed partly to a phenomenon known as the "centering effect." Due to this phenomenon, an iron core, when inserted into a current-carrying coil, automatically centers itself to the length of the coil. Also, if the core is suspended off center inside a coil without current, the core will center itself if current is applied to the coil. The centering effect is used in several electrical applications, such as solenoids, magnetic locks, and circuit breakers.

Exercises (015):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer

T F 1. Due to the centering effect, if an iron core is suspended within a coil without current, the core automatically centers itself to the length of the coil.

T F 2. The centering effect is used in the construction of magnetic locks, circuit breakers, and solenoids.

016. State a characteristic and an application of an electromagnet and the principle of relay operation.

Electromagnets and relays. If an iron core is installed in a fixed position within a coil, the device is known as an *electromagnet*. A frequent use of an electromagnet is in a relay. While relays are of many different sizes and shapes, they all operate on the principle that an electromagnet attracts magnetic substances (usually iron). Let's examine the parts of a simple relay and a simple relay-controlled circuit.

Figure 1-20 shows the parts of a relay: (1) an insulated coil of wire wrapped around an iron core and (2) a pivoting iron bar. When current is introduced into the coil, a magnetic field is created, represented by the broken lines. This attracts the pivoting bar. The iron bar can be used to close or open a circuit; consequently, a relay can be normally open or normally closed.

A relay can also be used to remotely control a neighboring circuit, such as the one seen in figure 1-21. When the switch is closed in the relay circuit, a magnetic field is created, which is represented by the broken lines. The iron bar in the adjacent circuit is attracted to the iron core and closes the adjacent circuit. If the switch is then opened in the relay circuit, the magnetic field around the coil collapses, allowing the spring to open the adjacent circuit.

Exercises (016):

In the exercises below, fill in each blank space with one or two words, as appropriate.

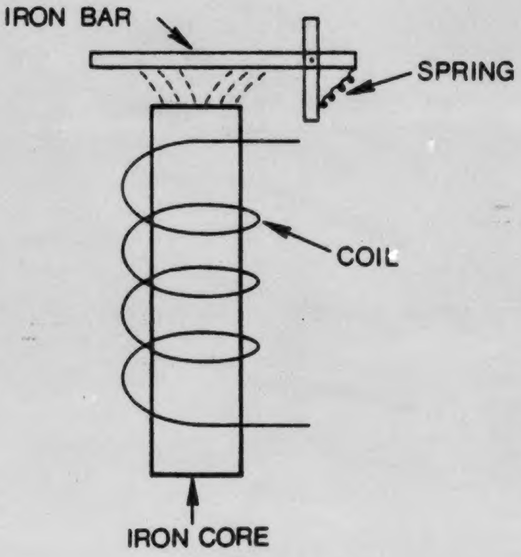


Figure 1-20. The parts of a relay.

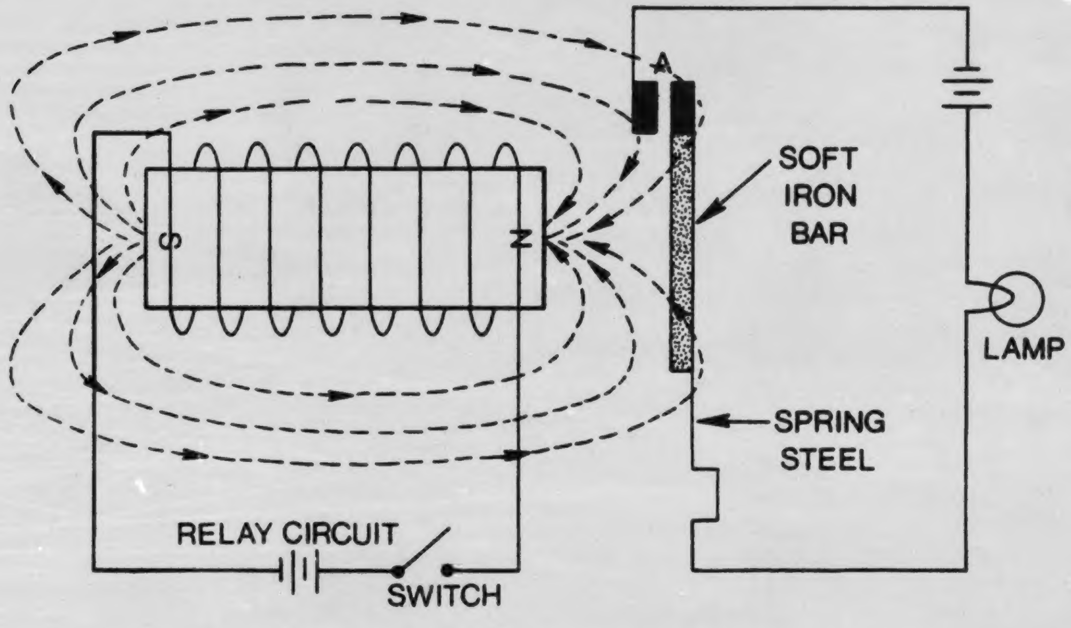


Figure 1-21. A simple relay controlled circuit.

1. The iron core in an electromagnet is in a __________ position within the coil.
2. A major use of an electromagnet is in a __________.
3. The principle of operation for a relay is that an electromagnet attracts __________ substances.
4. In a relay the contacts are closed or opened due to the attraction between the __________ and the __________ iron bar.
5. If a relay-controlled adjacent circuit is closed when current is flowing in the coil of the electromagnet, the adjacent circuit is __________ by __________ action.

017. Explain the operation of moving coil meters.

Moving coil meters. We now turn our attention to meters and meter movements, although we are still actually discussing electromagnetism, since it is this effect of current flow upon which most meter operations are based. (NOTE: Other effects of electricity are used to detect the presence or amount of electricity; however, our discussion is limited to meter operation based upon the electromagnetic effect.) The most common type of meter movement is the permanent-magnet, moving-coil movement, used in the d'Arsonval meter (fig. 1-22).

Basically, the operation of the meter is as follows: Direct current is introduced into several turns of copper wire wound around the moving coil. The current produces a magnetic field around the coil, which reacts with the magnetic field formed by the permanent magnet. The coil, which has become an electromagnet, turns on its axis as its poles attempt to repel like poles of the permanent magnet. An indicating needle mounted on the coil reads the degrees of rotation on the scale. The more current that passes through the coil, the greater is the repulsion or needle deflection, and thus the higher the reading on the scale.

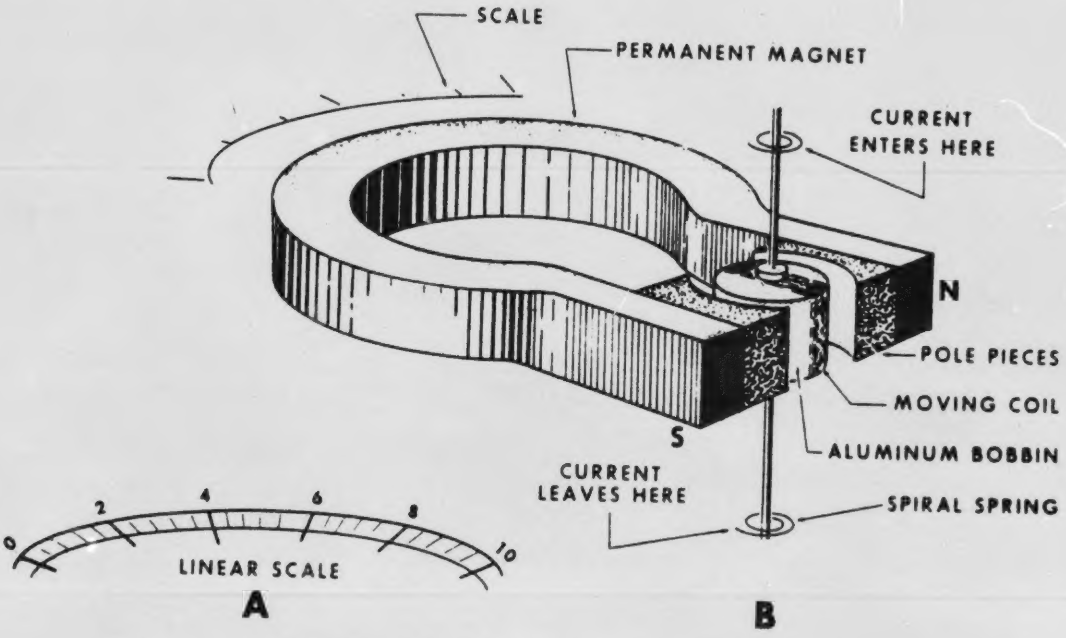
Meters with permanet-magnet, moving-coil movement are used in X-ray machines to measure such values as line voltage, kVp, mA, and mAs.

Exercises (017):

1. On what electrical current effect are most meter operations based?

2. What is the most frequent type of meter movement?

3. List the types of magnets in the d'Arsonval meter.



A. THE LINEAR SCALE B. THE PERMANENT-MAGNET-MOVING-COIL MECHANISM

Figure 1-22. A d'Arsonval meter.

4. What causes the moving coil to rotate in a d'Arsonval meter?

018. Compare electron movement in alternating current to electron movement in direct current.

Alternating Current Characteristics. Up to this point in this chapter, our discussions of current flow have been related to direct current, where electrons continuously flow in one direction through a circuit. Electron movement in alternating current (AC), on the other hand, is bidirectional; that is, electrons move first in one direction and then reverse themselves and move in the opposite direction. Keep in mind as you study AC that the electrons still move from negative to positive just as they do in DC since polarity also constantly changes.

Exercises (018):

Match the type of current in column B with the description of electron movement in column A by placing the letter of the column B item in the appropriate space in column A. Each column B item may be used once or more than once. Also, both column B items may match a single column A item.

Column A	*Column B*
___ 1. Electrons only move from negative to positive.	a. AC.
___ 2. Electron movement constantly changes directions.	b. DC.
___ 3. In a given circuit, electrons move through the wire conductor in the same direction.	

019. Cite salient characteristics of 60-cycle AC.

The characteristics of AC can best be understood by referring to a sine wave, as shown in figure 1-23. A sine wave shows the relative values of voltage and current plotted against time through 360°. Beginning with the horizontal line representing zero or no current flow, AC gradually increases in magnitude (voltage and current values) until a peak is reached. The peak values represent the maximum amplitude of the sine wave and are the maximum voltage and current in the circuit. For example, in an 110-volt circuit drawing 5 amps, those values are reached at that particular point in time that is also at 90° on a 360° scale. Before these "peak" values are reached, the voltage and current values gradually increase, beginning with zero. Once the peak values are reached, AC gradually decreases in value until zero on the sine wave, or no current flow, is reached. This second zero value is reached at 180° on a 360° scale. From this point, AC again increases in magnitude, but below the zero reference line, until a peak or maximum amplitude is reached and then once again decreases to zero, as shown in figure 1-23. This swing of the sine wave, however, represents a reverse in polarity or current flowing in the opposite direction from that above the zero reference line.

That portion of the sine wave above the zero reference line is known as the *positive alternation* or positive amplitude, and that portion below the reference line is known as the *negative alternation* or negative amplitude. These alternations are also referred to as impulses, or *pulses*. Two consecutive alternations are known as a *cycle*. As stated before, the sine wave represents AC values plotted against

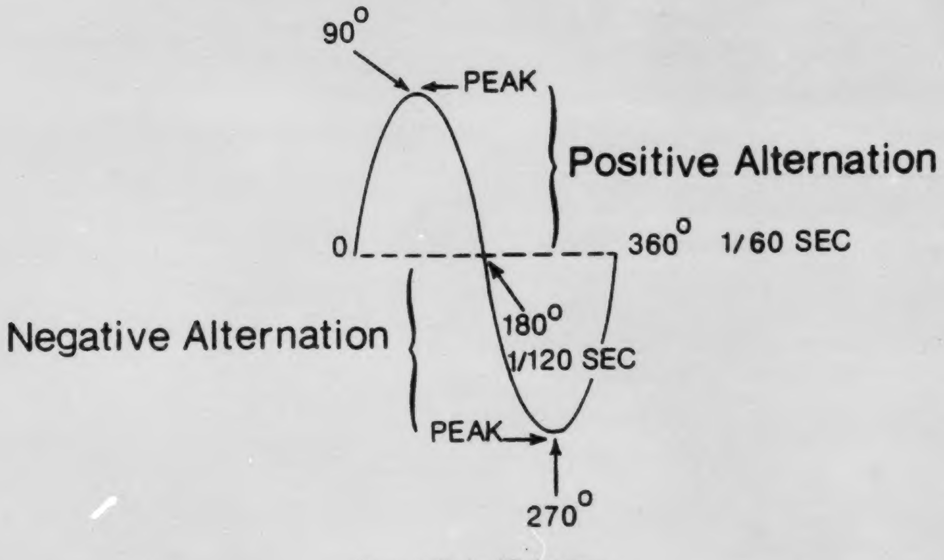


Figure 1-23. An AC sine wave.

time. In the case of 110-volt household current, there are 60 cycles per second. This means that 60 cycles or 120 alternations occur in 1 second. The number of cycles occurring in a second is referred to as the AC *frequency*. For our purposes in this CDC, we will deal mostly with 60-cycle AC, although much higher frequencies are used in other fields.

Exercises (019):

1. At what point in time during a cycle does the polarity of 60-cycle AC change?

2. During an AC cycle, is current continuously flowing in one direction or another? Explain.

3. How long does it take for 60-cycle AC to build from zero to the maximum current and voltage values?

4. How many alternations occur in one cycle?

5. How many pulses occur in one-half cycle?

6. What is AC frequency?

020. Define electromagnetic induction and answer key questions pertaining to the methods of inducing EMF in a conductor.

Electromagnetic Induction. If a conductor is moved through a magnetic field and cuts the lines of force or flux, as illustrated in figure 1-24,A, an EMF is induced in the conductor. By the same token, if the conductor is stationary and the magnet moves, as illustrated in figure 1-24,B, an EMF is also induced in the conductor. This process of producing an EMF from the relative motion between a conductor and magnetic field is called *electromagnetic induction*. Accordingly, there are three requirements for electromagnetic induction: (1) a conductor, (2) a magnetic field, and (3) relative motion.

The magnitude of the induced EMF depends upon the number of lines of force cut per unit time; the greater this number, the higher the induced EMF. Two ways of increasing the induced EMF are: (1) to increase the relative motion or speed at which the lines of force are cut and (2) to increase the strength of the magnetic field. The magnitude of the induced EMF also depends upon the number of conductors in which the EMF is induced; the more conductors—or as we shall see when we discuss transformers, the more turns in a coil—the higher the induced EMF.

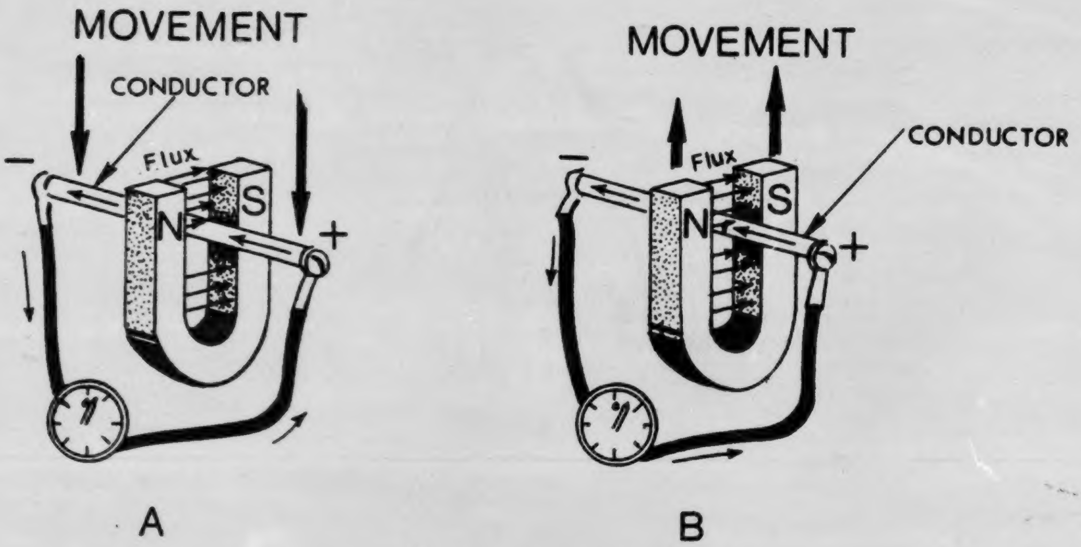


Figure 1-24. Electromagnetic induction.

Exercises (020):

1. Define electromagnetic induction.

2. What are the three requirements for electromagnetic induction?

3. Explain the relationship between the magnitude of the induced EMF and the relative motion and strength of the magnetic field.

4. Explain the relationship between the magnitude of induced EMF and number of conductors in which the EMF is induced.

021. Given a list of statements pertaining to self-induction and mutual induction, indicate which are true and which are false. If you indicate "false," explain your answer.

Self-induction. Now that we have reviewed some basic information about electromagnetic induction, let's see how we can induce an EMF or current in a conductor without moving the conductor or the magnet. Refer to figure 1-25. Detail A shows a conductor formed into a coil, and detail B shows an AC sine wave. When the current in the coil corresponds to zero in detail B, there is actually no current present in the coil. From zero to one, the current is increasing in the direction indicated by the arrows on the coil. You will recall that when we have current in a conductor, we have a magnetic field around the conductor. We have shown the field at only two points in the coil, although it is actually present all along the conductor. Now you can see that we have two of the three requirements for induction: (1) a conductor, and (2) a magnetic field.

Now let's see where the relative motion comes from. As the current increases during the interval from zero to one, the magnetic field increases in strength and expands to a point where it cuts the conductor in other loops, as shown in detail C of the figure. As the AC decreases from maximum to zero during the interval of one to two in detail B, the magnetic field decreases in strength. As the field decreases, it cuts the loops in the opposite direction. This expansion and collapse of the magnetic field, which is a result of the increasing and decreasing AC values, in part provides the relative motion necessary to induce EMF or current into the other loops of the conductor. The change in direction of AC current flow also changes the directions of the magnetic field, providing additional relative motion. When the magnetic field of a coil induces current into the coil itself, the process is known as *self-induction.*

Mutual induction. Mutual induction is defined as the process of introducing current or voltage in a circuit by varying the current or voltage in a neighboring circuit. Figure 1-26 shows an AC generator furnishing power to coil a. Coil b is not electrically connected to coil b. As the expanding and collapsing magnetic field around coil a cuts the loops of coil b, current or voltage is introduced into coil b. Again notice the three requirements for induction with the relative motion resulting from the expanding and collapsing magnetic field.

Exercises (021):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. During self-induction, relative motion results in part from increasing and decreasing AC values.
T F 2. Self-induction and mutual induction both make use of an expanding and collapsing magnetic field.
T F 3. Mutual induction occurs only if one coil is located within the magnetic field of another coil.

022. Define transformer action; and given data pertaining to two transformers—turns ratio, input voltage, and input current—determine the output values of each transformer.

Transformers. This section is actually a continuation of the discussion of electromagnetic induction, since a transformer is an electrical device that operates on the principle of mutual induction. First, let's define "transformer action." Transformer action is the process of transferring electrical energy from one circuit to another by electromagnetic induction.

Step-up and step-down transformers. A transformer that increases the voltage is called a *step-up transformer;* whereas, one which decreases the voltage is called a *step-down transformer.* The factor that determines whether a transformer steps up or steps down the voltage is the turns ratio. "Turns ratio" is defined as the ratio of the number of turns in the primary winding (first coil) to the number of turns in the secondary winding (secondary coil). For example, the turns ratio of the transformer shown in figure 1-27, detail A, is 5 to 1, and that of the transformer in figure 1-27, detail B, is 1 to 4.

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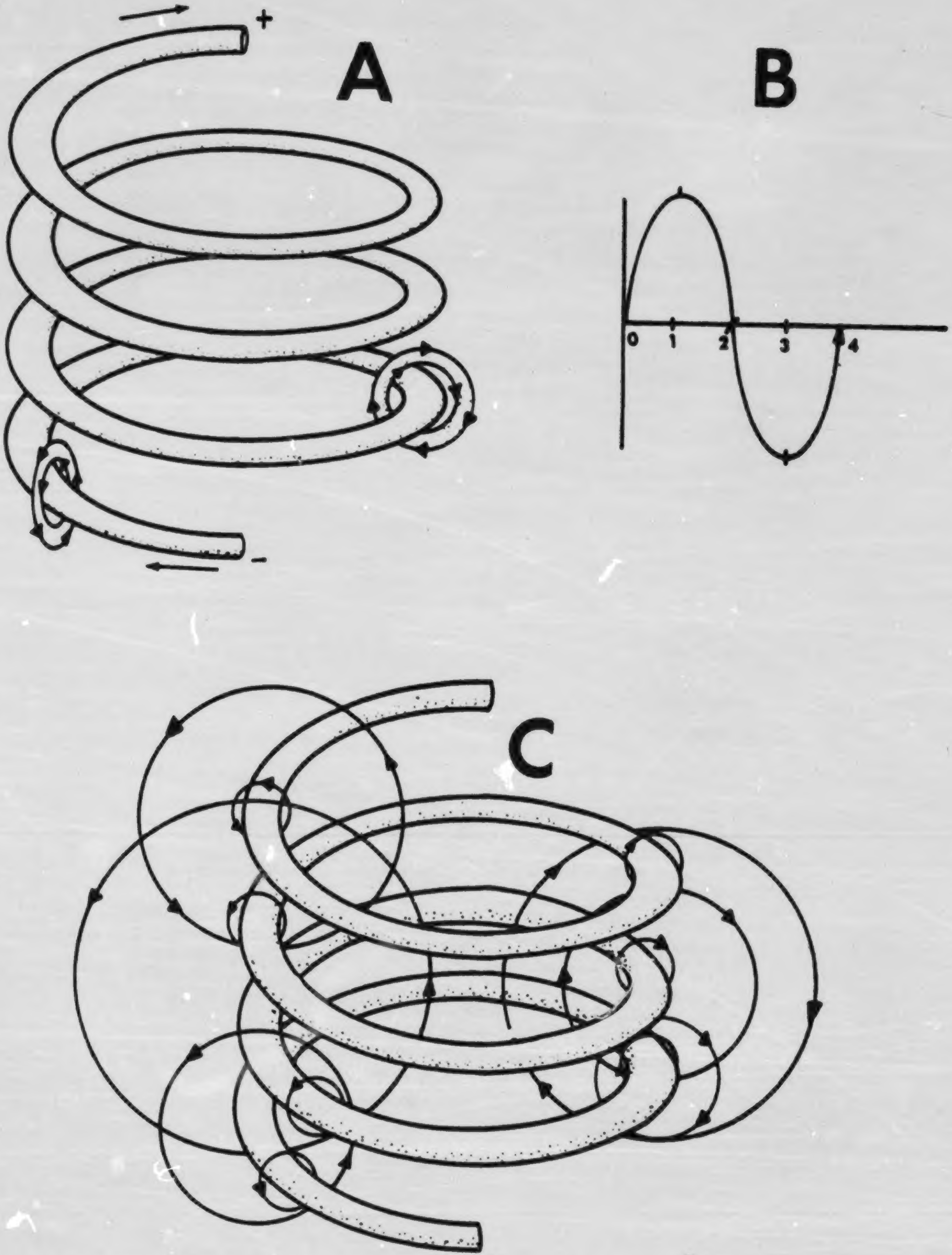

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Figure 1-25. Self-induction.

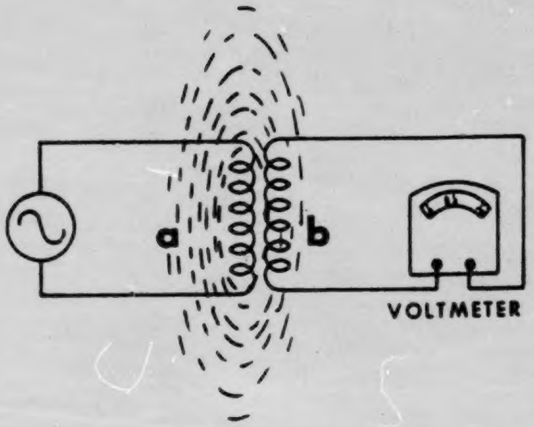


Figure 1-26. Mutual induction.

Now let's consider transformer actions. What effect does the turns ratio have on the transformer output? The ratio of the transformer input to the output is the same as the turns ratio, provided the transformer is 100 percent efficient. (NOTE: Transformers are not 100 percent efficient, but for ease of calculation we will consider them to be.) In other words, an input of 10 volts applied to the primary of the transformer in detail A, will induce 2 volts in the secondary. Therefore, this is an example of a step-down transformer. Contrariwise, an input of 10 volts applied to the primary of the transformer shown in detail B will result in an output of 40 volts from the secondary. So detail B is an example of a step-up transformer. No matter what voltage we apply to the primary of the transformer in detail A, the output is one-fifth of the input (assuming we stay within the voltage limits of the transformer). With the transformer shown in detail B, the output is four times the input. This shows that the turns ratio determines the step-up or step-down ratio of a transformer.

Now, let's see what happens to the current. We find that a transformer that increases the voltage by a given ratio decreases the current by the same ratio. In other words, if we apply 10 volts at 10 amps to the primary of a 1 to 10 step-up transformer, as shown in figure 1-28, detail A, the voltage in the secondary will be 100 volts and the current will be 1 amp. If the transformer is a step-down transformer, as shown in figure 1-28, detail B, the current in the secondary will be increased by the same ratio that the voltage is decreased.

Exercises (022):

1. Define "transformer action."

2. What is the output voltage and amperage from a transformer using the following information: Input voltage - 110 volts; input amperage - 5 amps; transformer ratio - 10 to 1?

3. What is the output voltage and amperage from a transformer using the vollowing information: Input voltage - 220 volts; input amperage - 3 amps; transformer ratio - 1 to 3?

023. State the purpose and basic operation of an autotransformer and explain "red-lining."

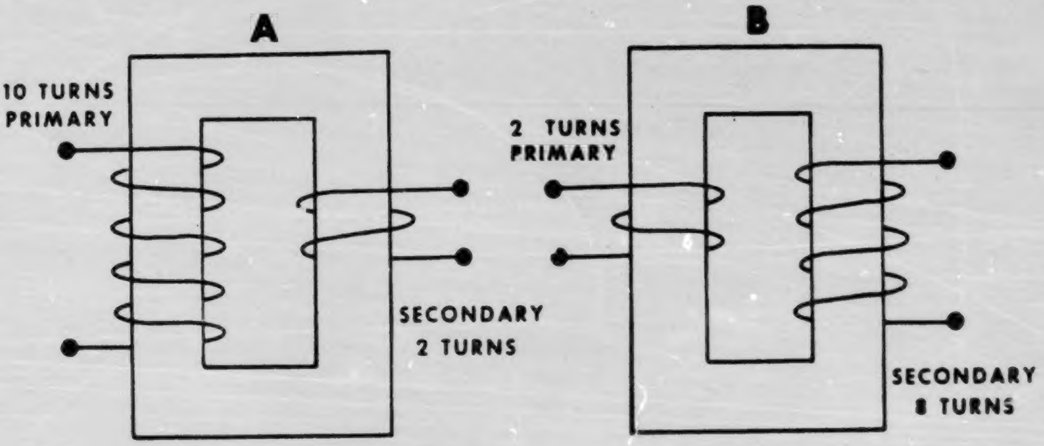
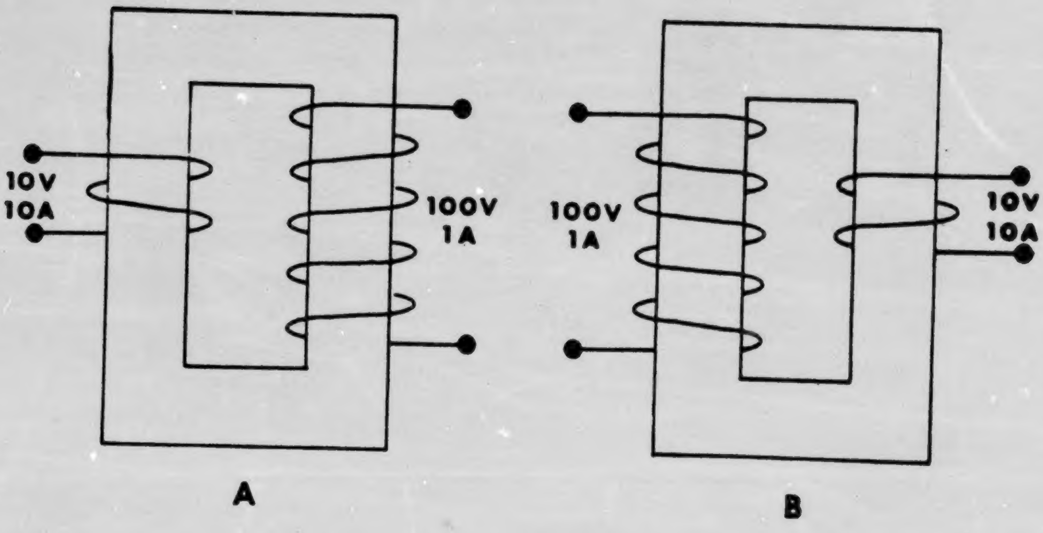


Figure 1-27. Transformer turns ratio.



A. STEP-UP B. STEP-DOWN

Figure 1-28. Transformer turns ratio.

Autotransformers. As a radiologic technologist, you are concerned with three transformers. By now you are familiar with the step-up and step-down transformers. The third type, and probably the most important one to you, is the autotransformer. The autotransformer is the most commonly used and most efficient method of varying the kilovoltage output of the high tension transformer in the X-ray machine. Consider for a moment a transformer consisting of one continuous winding on a long, laminated iron core. When voltage is applied across only one section of it, voltage will be induced in the turns that are not connected directly to the line in the same way that voltage is induced in the secondary coil of a conventional transformer.In fact, the section across which the line voltage is applied is called the primary, and the balance of the winding is called the secondary.

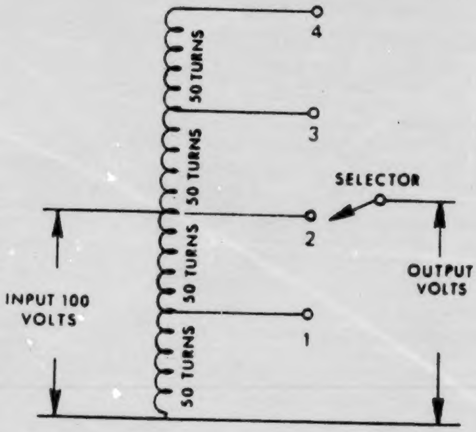


Figure 1-29. Autotransformer circuit—constant volts per turn.

If the voltage is measured across various sections of a typical autotransformer, a situation like that in figure 1-29 may be present. A series of taps or connections to the different turns provides a convenient method of getting a wide variety of voltages to apply to the primary of the high tension transformer. In the circuit shown in figure 1-29 (this circuit has a constant number of volts per turn), the following voltages could be acquired by setting the selector switch on the various taps:

- Tap #1—50 volts.
- Tap #2—100 volts.
- Tap #3—150 volts.
- Tap #4—200 volts.

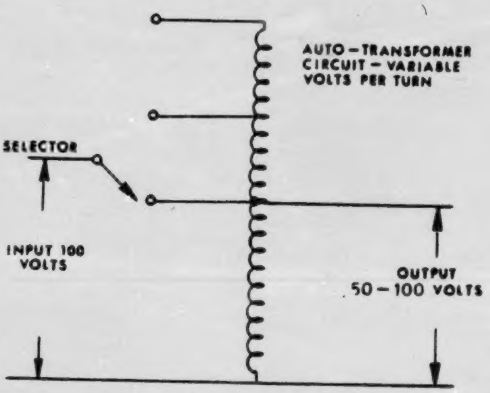


Figure 1-30. Autotransformer circuit—variable volts per turn.

The same results can be obtained by connecting the line to a number of selected taps and leaving the output connected to a given pair of taps, as in figure 1-30. In actuality, autotransformers are usually provided with many taps in the primary as well as the secondary circuit, with the result that you have an almost unlimited choice of voltage outputs. The autotransformer becomes in this way the basic regulatory source of all the supply voltages needed for operating the many components of the X-ray generator.

If you will look at figure 1-31, you will see that one side of the supply line is connected through a line voltage compensator control. You adjust this control on your X-ray control panel to obtain a predetermined reading on the line voltage indicator or line voltage compensator meter. This meter, sometimes referred to as a "red-line meter" (the process of adjusting the line voltage compensator is sometimes referred to as "red-lining the machine") is connected across a few turns on the autotransformer and is an indication of the volts per turn in the transformer. When this meter is correctly adjusted, you are assured that the output of the autotransformer will always be the same between a given set of taps, regardless of the line voltages. If your machine is not red-lined, your exposure will be lighter or darker than normal, since voltage across the X-ray tube is not consistent with the setting on your control panel.

This compensated voltage is picked off by the major and minor kVp selectors (which you adjust on the X-ray machine control panel) and supplied to the primary of the high tension transformer. In figure 1-31 the selector marked MAJOR is connected to a series of taps, between which there are relatively large differences in voltage. The selector marked MINOR gives you small voltage changes. Usually there are 10 steps on the minor selector that give you the same change in voltage as going from one step to the next on the major selector. With a combination of 10 major and 10 minor steps you can get 100 different output voltages.

Exercises (023):

1. Why is an autotransformer used in an X-ray machine?

2. What is meant by "red-lining" a machine?

3. If an X-ray machine is not red-lined, how and why is the film exposure affected?

4. What parts of the autotransformer should be adjusted to control the voltage supplied to the high tension transformer, and on which side of the autotransformer are they located?

024. Given a list of waveforms across various X-ray tubes, match each with related factors, such as AC power, type of rectification, X-ray production, and use of negative alternations.

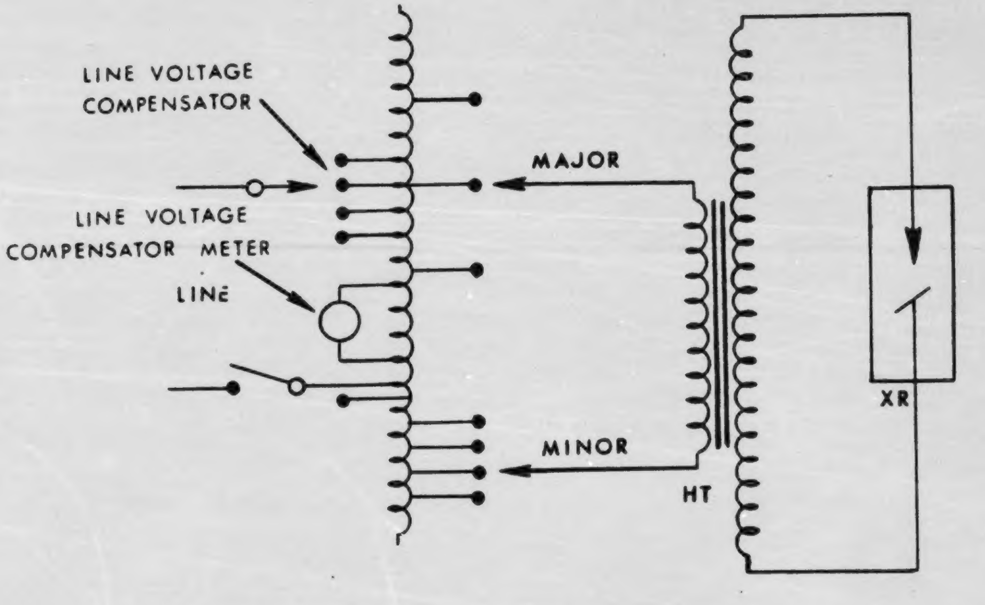


Figure 1-31. Autotransformer circuit—dual selectors.

Rectification. Rectification is the process of converting AC power to pulsating DC. This conversion is necessary in the X-ray machine because X-ray tubes are designed to operate on pulsating DC. Our discussion of rectification is based on the resulting waveforms across the X-ray tube. We will consider the waveforms from two aspects—single-phase and three-phase X-ray generators.

First of all, let's briefly review single-phase and three-phase AC. You will recall our discussion of the AC sine wave when we discussed the wave representing the AC voltage and current values. The sine wave of 60-cycle AC consists of a single wave that occurs during 1/60 second or one cycle. That type of AC is called single-phase AC, and an X-ray machine operating from single-phase AC is called a single-phase generator. Three-phase AC, on the other hand, consists of three sine waves per cycle separated by 120°, as shown in figure 1-32, which also shows a comparison with single-phase AC. An X-ray machine designed to operate on three-phase AC is called a three-phase generator.

You will also recall that the sine waves below the zero reference line (negative alternations) represent current flowing in the opposite direction from those above the line. Rectification consists of rerouting these negative alternations so that they travel in the same direction as the positive alternations, or in the case of older, small-capacity, single-phase generators, the negative alternation is eliminated altogether.

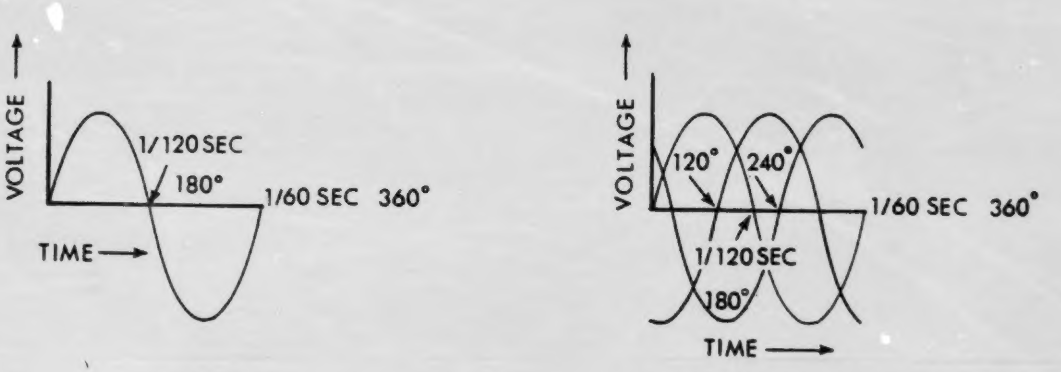
Single-phase waveforms. As previously mentioned, rectification in some of the older X-ray machines, mostly portable units operating on single-phase AC, consists of eliminating the negative alternation. These are either self-rectified or half-wave rectified units. The resulting waveform across the X-ray tube, referred to as one-pulse, is shown in figure 1-33. You can see from the figure that voltage is only applied across the X-ray tube for half of a given time period. For example; during a period of 1/60 second, voltage occurs for 1/120 second. During the other 1/120 second, there is no voltage and no X-ray production.

A two-pulse waveform, also shown in figure 1-33, is produced in a single-phase generator, using full-wave, bridge rectification. Many old, as well as new, X-ray machines use full-wave rectification. With this type of rectification, the negative alternation is rerouted in the same direction as the positive alternation, and this produces two pulses per cycle across the X-ray tube. In comparison with a one-pulse waveform, the two-pulse produces twice as much radiation in a given time period if all other factors are equal.

Three-phase waveforms. A three-phase X-ray generator produces either six pulses or twelve pulses per cycle across the X-ray tube, depending upon the type of transformer. Both of these are illustrated in figure 1-33. If a three-phase generator produces a six-pulse waveform, the negative alternations are redirected in the same direction as the positive alternations. In the case of a six-pulse waveform, the negative alternations are redirected and in case of twelve-pulses, the six-pulses are doubled by means of a special transformer that produces a phase shift in the secondary winding. This results in an additional six pulses of current when rectified—three more positive and three more negative pulses across the X-ray tube, all in the same direction.

Exercises (024):

Match the waveform in column B with the appropriate response in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or



SINGLE - PHASE AC

THREE - PHASE AC

Figure 1-32. Single-phase and three-phase AC.

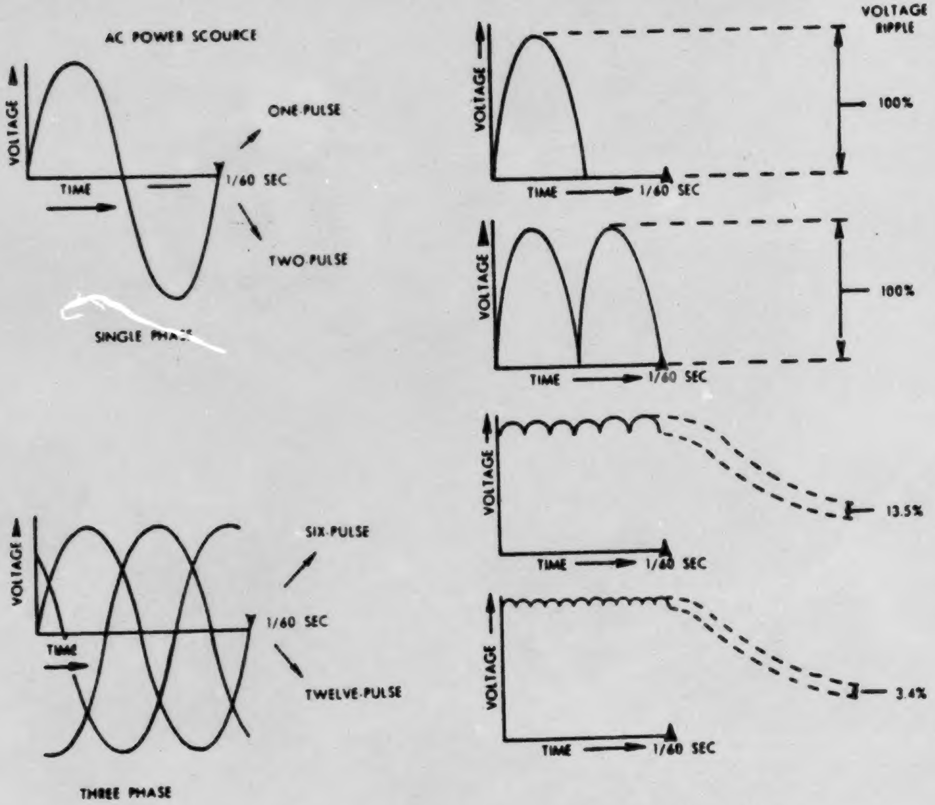


Figure 1-33. Comparison of waveforms produced by different types of rectification.

more than once. In addition, two or more column B items may match a single column A entry.

Column A

___ 1. Single-phase AC.
___ 2. Self-rectification.
___ 3. Three-phase AC.
___ 4. Produces X-rays only half of a given time period.
___ 5. Three negative alternations per cycle are directed across the X-ray tube.
___ 6. X-ray production is twice that of one-pulse for a given time period.
___ 7. Negative alternation is eliminated.
___ 8. Six negative alternations per cycle are directed across the X-ray tube.

Column B

a. One-pulse.
b. Two-pulse.
c. Six-pulse.
d. Twelve-pulse.

025. Relate average electron energies to X-ray tube waveforms.

Effect of waveform on average electron energy. Look again at figure 1-33 and notice the *voltage ripple* for the four voltage patterns. As you can see, it is 100 percent for one- and two-pulse, 13.5 percent for six-pulse, and only 3.4 percent for twelve-pulse. Voltage ripple, as you have probably already determined from the figure, is the difference between the peak voltage and the minimum voltage of each pulse. To put this in perspective, refer to figure 1-34, which shows a wave pattern produced in a single-phase, two-pulse generator and another produced in a three-phase, twelve-pulse generator. With the two-pulse wave, the voltage rises to a peak and then falls to zero (100 percent ripple). This rise and fall of the voltage causes the speed of the electrons across the X-ray tube, an important factor in X-ray production, to vary accordingly. Consequently, if 100 kVp is applied to the X-ray tube, the kinetic energy of the electrons theoretically ranges from zero when the voltage is at zero, to 100 keV when the voltage value is at its peak. As you know, keV, stands for kiloelectron volts and is a unit of energy. The twelve-pulse wave from a three-phase gnerator does not drop to zero. As stated earlier, it only drops 3.4 percent below peak value. As a result, the kinetic energy of the electrons only drops 3.4 percent below the peak kV value. In other words, the kinetic energy of the electrons (at 100 kVp) in a twelve-pulse system theoretically ranges

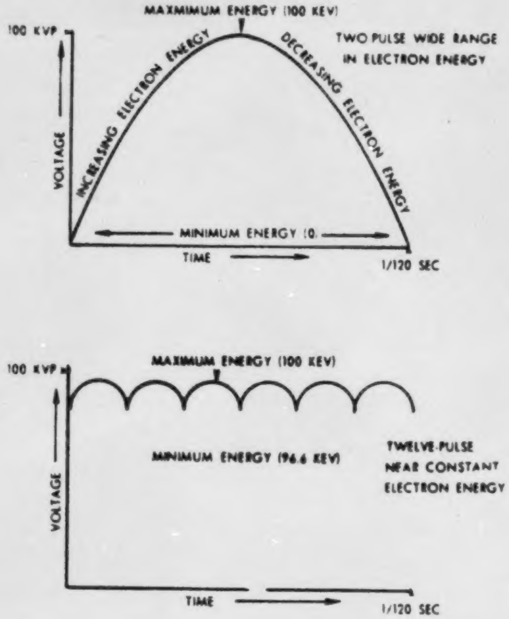


Figure 1-34. Comparison between electron energies of 2-pulse and 12-pulse waveforms.

from 96.6 keV to 100 keV. This means that the average kinetic energy imparted to the electrons is much higher in the twelve-pulse system than in the two-pulse system. Following this same line of reasoning, you can see that the average electron energies of one-pulse and six-pulse waveforms also vary according to the voltage ripple.

Exercises (025):

1. Explain the connection between waveform and voltage ripple.

2. What important factor in the production of X-rays does voltage ripple affect?

3. What type of generator produces the highest average electron energies?

4. Compare the average electron kinetic energies of six-pulse and twelve-pulse waveforms.

5. Compare the average electron kinetic energies of one-pulse and six-pulse waveforms.

026. Relate electron energy to photon energy, and compare the average photon energies and the beam-penetrating power of single- and three-phase generators.

Effect of average electron energy on photon energy. We can determine the significance of the higher average kinetic energy of the electrons by examining the effect of electron energy on photon energy. When low-speed (low-energy) electrons strike the target in an X-ray tube, their energies are converted either into heat or into low-energy photons. Consequently, since a single-phase generator produces comparatively more low-energy electrons, it also produces a greater proportion of low-energy photons than does a three-phase generator. The greater proportion means that the average photon energy is less in a single-phase generator. Low-energy photons from the target of an X-ray tube are absorbed either by filtration or by the patient. In either case, they usually serve no useful purpose in diagnostic radiology since they do not reach the film and contribute to the exposure.

The penetrating power or quality of a beam of X-rays is governed by average photon energy; in a three-phase beam the average photon energy is greater than in single-phase, assuming that both systems are operated at equal peak kilovoltages. Notice that the qualitative difference in the two beams is in *average* photon energy. Both systems do, in fact, produce low-energy photons. The difference is in the proportion.

Exercises (026):

1. What is the relationship between electron energy and photon energy?

2. How do the average photon energies of single-phase and three-phase X-ray beams compare?

3. What type of X-ray generator produces a more penetrating beam of X-rays (assuming both are operated at equal peak kilovoltages)?

027. Compare the beam intensities of a single-phase and a three-phase generator, and explain the reason for the difference.

Comparison of beam intensities between single-phase and three-phase generators. The intensity of an X-ray beam is greater with a three-phase generator than with a single-phase system for a given tube current. Therefore, the twelve-pulse system produces a given amount of radiation in a much shorter period of time than does the two-pulse system. Figure 1-35 shows two-pulse and twelve-pulse waveforms. Notice that image-forming radiation is only produced at certain times with two-pulse. At other times, either no radiation at all is produced (when the sine wave is at zero value) or radiation is produced that has insufficient energy to reach the film. The twelve-pulse wave continuously produces image-forming radiation because of its near constant voltage level.

Exercises (027):

1. How does the intensity of an X-ray beam from a single-phase generator compare to that of a three-phase generator if both are operated at equal tube current?

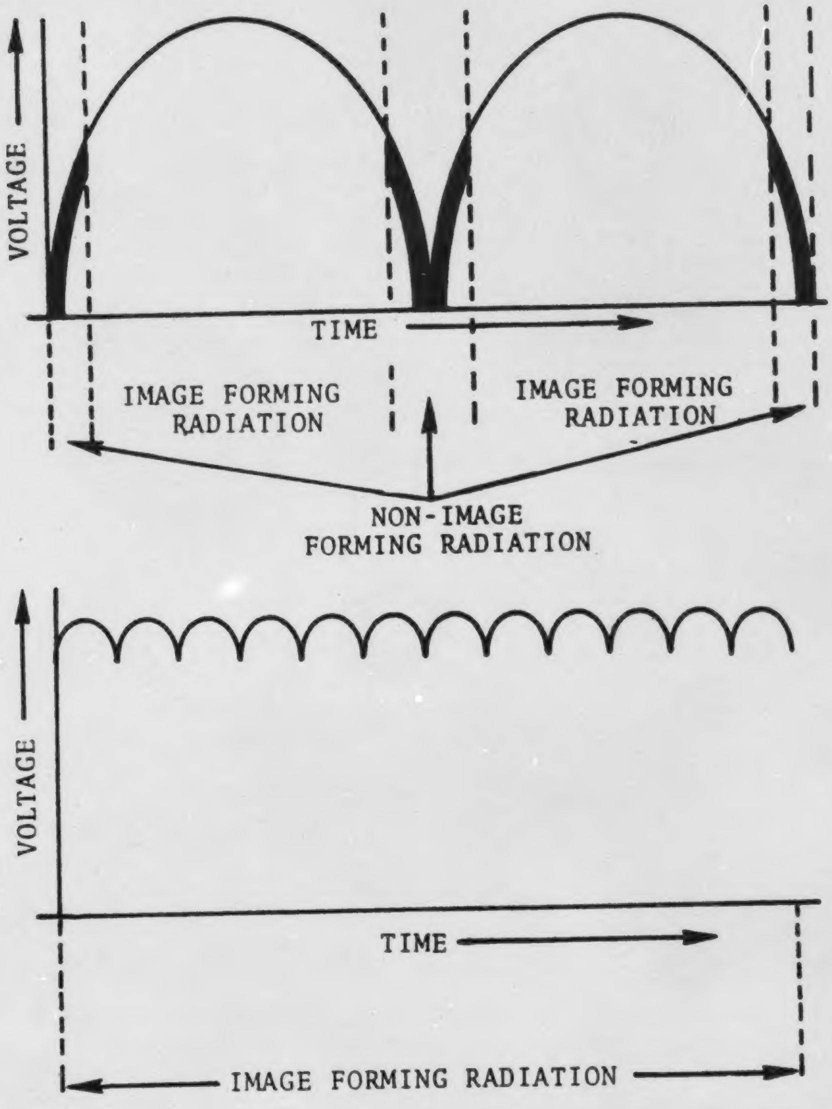


Figure 1-35. Comparison of time periods of single-phase and three-phase when image forming radiation is produced.

2. Why is there a difference between the beam intensities as described in exercise #1 above?

028. Convert the kVp used on a three-phase unit for use on a single-phase unit, and explain why the conversion is made with the kVp.

Technique conversion factor between single- and three-phase generators. The average energy level of the beam of radiation produced by a three-phase unit is higher than that produced by a single-phase unit when both are adjusted for the same peak kV. Therefore, to produce radiographs with the same general scale of contrast, it is necessary to use higher kVp with the single-phase unit. For a given mA station, it requires approximately twice as much exposure time for a single-phase unit as for a three-phase (twelve-pulse) unit. Therefore, it is more logical to make the technique compensation with kVp rather than with mAs. Increasing the (single-phase) kVp by 15 percent increases the average energy of the beam to a point where the single-phase unit produces radiographs of approximately the same scale of contrast (and density) as those produced by the three-phase unit, using the same mA and time (mAs) factors. In addition, the increase in kVp tends to keep the absorbed dose of the patient to a minimum.

Exercises (028):

1. If 92 kVp is used for an exposure on a three-phase unit, what kVp should be used for the same exposure on a single-phase unit (assuming all other factors are equal)?

2. Why is the exposure conversion in exercise #1 above made with the kVp rather than with some other exposure factor?

029. Compare the X-ray tube capacity for a single-phase and a three-phase generator.

Comparison of X-ray tube capacities between single- and three-phase generators. X-ray tube capacity is greater in a three-phase system for short exposures. One reason for the increased tube capacity is that the heat is spread over a larger area on the target. Figure 1-36 shows two rotating targets. Assume that each is subjected to an exposure of 1/60 second. Target A is exposed by a single-phase, two-pulse system, while target B is exposed by a three-phase, twelve-pulse system. Target A shows two "hot spots" which correspond to the peak of the two pulses produced at 1/60 second. Therefore, the point heat buildup at these "hot spots" determines the maximum capacity of the tube on a short exposure. Target B, on the other hand, shows no "hot spots" due to point heat buildup. The absence of the "hot spots" results in a more even thermal load. In this manner the anode disk is fully exploited for X-ray production. The increased thermal capacity for X-ray tubes operated on three-phase is increased only for exposures less than one-half second. From one-half to 1 second, the ratings are approximately the same as for single-phase. Above 1 second, the ratings are usually greater for X-ray tubes operated on single-phase.

Exercises (029):

1. For exposures less than one-half second, an X-ray tube operated with what type of generator will have greater capacity? Why?

2. How do single- and three-phase tube capacities compare for exposures of one-half to 1 second?

3. How do single- and three-phase tube capacities compare for exposures greater than 1 second?

1-2. X-Ray Tubes

X-ray tubes have undergone considerable change in the past few years. Some of the changes include smaller focal spots, higher capacity, and shorter exposure times. In this section we will discuss these and other aspects of X-ray tubes, as well as tube-rating charts. We will also provide a brief review of the parts of an X-ray tube.

030. Show the influence of the X-ray tube cathode an overall tube operation.

Tube Considerations. Our discussion of the X-ray tube itself begins with the cathode. With newer X-ray tubes, the cathode is becoming more and more important in overall tube operation.

The cathode. The cathode consists of the filament inclosed in a molybdenum or nickel alloy focusing cup. The purpose of the focusing cup is to "aim" the electrons at a specific area on the anode. The filament, when heated to incandescence, is the source of free electrons that interact with the tube target to produce X-radiation. As the filament becomes heated, freed electrons form a cloud around the filament (this is known as thermionic emission). The length of the filament, along with the

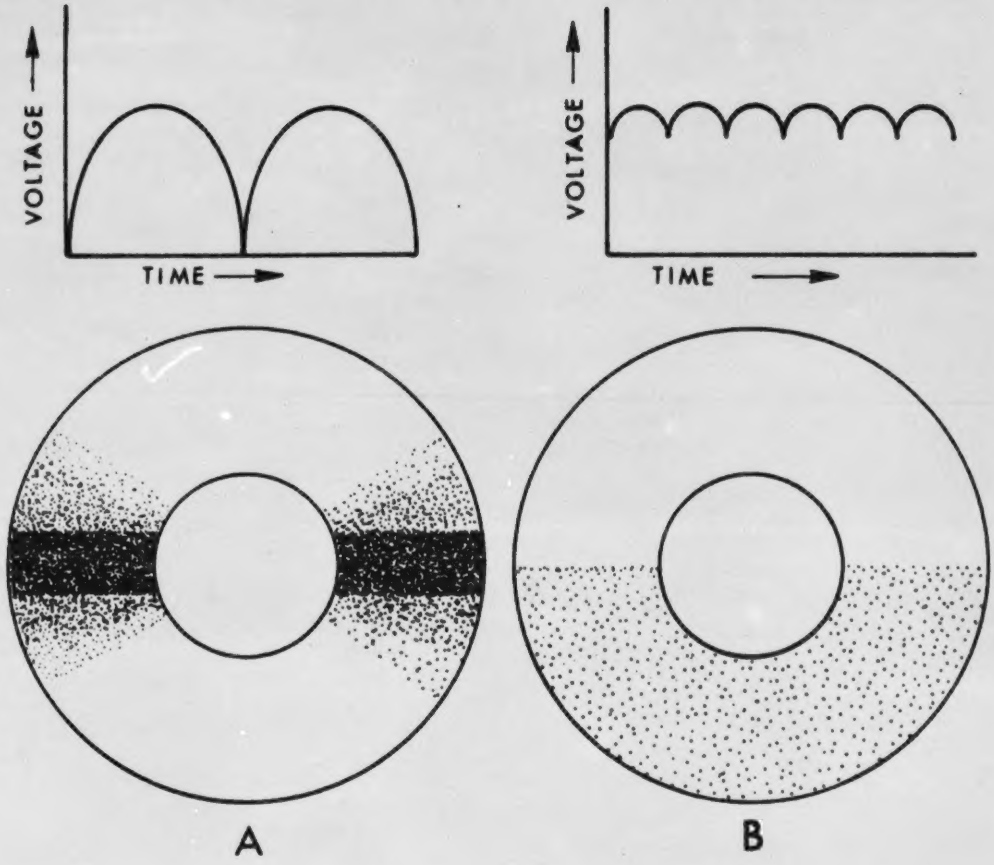


Figure 1-36. Comparison of point heat buildup between single- and three-phase generators.

size and shape of the focusing cup, influences the size of the focal spot. Most X-ray tubes have two filaments and therefore two focal spots. One filament is large or long, and the other is small. This arrangement increases the capabilities of the X-ray tube. The small focal spot is designed to give maximum detail, but its operating time is limited because of the great amount of heat that is generated in the small area of the target when high techniques are used. Therefore, to spread the heat over a larger area, a large filament is included. This large filament allows you to increase the techniques within certain limits, yet not damage the target through overheating. When the large focal spot is used, the heat spreads over a larger surface area of the target and is dissipated at a faster rate than when the small focal spot is used.

An X-ray tube filament is made of tungsten, and the life of the filament is determined in part by the length of time it is maintained in a "boost" condition. By "boost," we mean the short period of time before exposure when the filament is heated to the required emission temperature. The boost condition begins when you depress the STAND-BY or ROTOR button of your exposure switch. The condition also automatically begins when you depress the EXPOSURE button. The tendency of tungsten to vaporize at high temperatures, with the resultant deposit of the vaporized tungsten on the glass wall of the tube, causes erratic tube operation and eventual permanent damage. For this reason, it is obvious that you should not use the STAND-BY button unless absolutely necessary and then use it only for a short time.

Exercises (030):

1. What is the purpose of the focusing cup in an X-ray tube?

2. From what part of the cathode are the free electrons emitted?

3. What filament characteristic affects the size of the focal spot?

4. If your exposure for a particular radiograph is relatively high, which tube filament would you probably be using?

5. Explain the "boost" condition.

6. What action should you take to prevent vaporization of the filament?

031. Answer key questions pertaining to the X-ray tube anode.

The anode. The X-ray tube anode contains the target in which the electrons interact with the target material to produce X-radiation. The anode is positively charged with respect to the cathode and thereby provides the difference in potential necessary to set the free electrons in rapid motion. The target itself is usually made of tungsten although some of the newer targets are constructed of a rhenium-tungsten alloy that makes them more resistant to surface etching at high temperatures. Tungsten is used because of its high melting point and high atomic number.

The *actual focal spot* is that area of the target bombarded by the electrons (see fig. 1-37). Its size significantly affects the heat-loading capacity—the larger it is, the greater the heat-loading capacity. Its size is determined in part by a combination of three factors: the size and shape of the filament, the size and shape of the focusing cup, and the angle of the target surface. The *effective focal spot* is the focal spot as it appears from directly beneath the tube at right angles to the electron stream (see fig. 1-37). Its size is very important because it significantly affects the detail on a radiograph. (Focal spot size and detail are discussed at length in Chapter 2.) The size of the effective focal spot is determined in part by the size of the actual focal spot and the angle of the target surface.

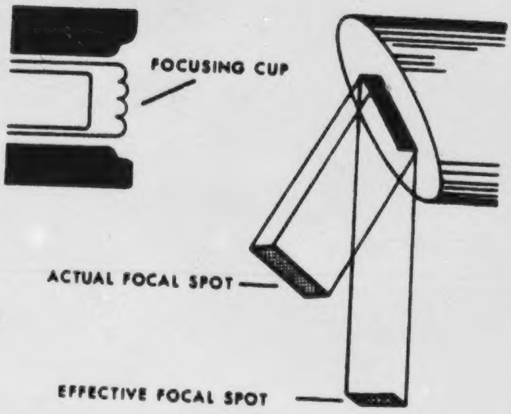


Figure 1-37. Actual and effective focal spots.

As you can see from the previous paragraph, for maximum effectiveness we need an X-ray tube with an actual focal spot large enough to permit the necessary heat loading and an effective focal spot small enough to produce optimum detail. This is accomplished in part by the application of the *line focus principle*. For the purpose of line focus, the X-ray tube is designed so that the electrons bombard a rectangular area on the target surface. A specific target angle then produces an effective focal spot that is approximately square and much smaller than the actual focal spot. Figure 1-38 shows two different targets with angles of 20° and 40°. As you can see, both targets produce effective focal spots of equal size, but the actual focal spot at 20° is larger. Consequently, the 20° target produces a relatively large actual and a relatively small effective focal spot.

In actual practice, targets are usually angled less than 20°, some as little as 7°, which further aids in obtaining high heat loading and optimum detail. However, targets with small angles may create a problem that is not significant with larger angles. The problem is in the area of X-ray coverage, or, put another way, the area that the X-ray beam will

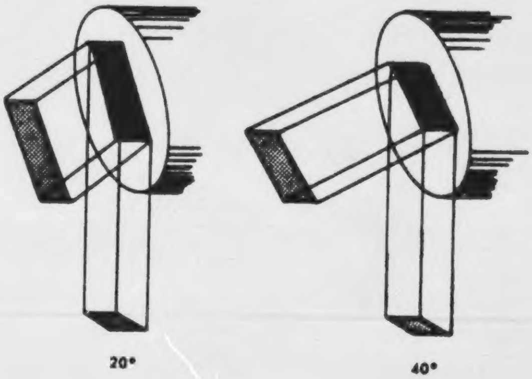


Figure 1-38. Comparison of focal spots of different target angles.

cover. For example, a target with a 10° angle at a 40-inch FFD covers only a 14-inch-square area, and a 7° angle only covers a 9.5-inch-square field. Obviously these tubes cannot be used to radiograph an AP abdomen at 40 inches since the beam will not cover the entire abdomen. Tubes of this type can be used effectively, however, where X-ray coverage is not so critical as is the requirement for good detail, as in an angiographic room, where the beam will cover smaller films in automatic film changers. A 12° target is the smallest angle that adequately covers a 14- by 17-inch film at a 40-inch FFD.

One recent development in tube focal spots is a biased focal spot. Due to the inherent design of X-ray tubes, electrons striking the target have a tendency to concentrate on the outer sides, resulting in more X-ray photons being produced at those locations. In effect, this situation produces two sources of X-ray photons, which may produce double images on the film. The double image is particularly a problem if small vessel magnification radiographs are being performed. To overcome the problem, a negative bias voltage is applied to the cathode, which concentrates the electrons more in one spot on the target, thus providing a single source of X-ray photons.

Exercises (031):

1. What anode condition causes the free electrons to be set in motion?

2. In what part of the X-ray tube are X-ray photons produced?

3. Why is tungsten used as target material?

4. Of what significance is the actual focal spot?

5. Name two factors which affect the size of the effective focal spot.

6. Explain the line-focus principle.

7. Explain the relationship between target angle and film coverage.

8. What is the smallest target angle that covers a 14- by 17-inch film at a 40-inch FFD?

9. What type of focal spot is advantageous when performing small vessel magnification radiographs and why?

032. Give two advantages of a grid-controlled X-ray tube, and explain the factors that produce these advantages.

Grid-controlled tube. To prevent relay damage due to arcing, an X-ray exposure is normally synchronized to the line voltage so that it begins and ends when the sine wave is at zero value. Using this system in a single-phase generator, the shortest exposure possible is 1/120 second, since the sine wave reaches zero value every 1/120 second. With a grid-controlled tube, the exposure is also synchronized with the line voltage, but it does not necessarily begin and end at zero value. It can be synchronized to a particular portion of the sine wave. Figure 1-39 shows two waveforms with exposures of 1/120 second on a conventionally timed tube and 1/360 second on a grid-controlled tube. Since the conventional exposure should begin and end at zero value, it must encompass one complete pulse. On the other hand, the grid-controlled exposure indicated here includes only the middle third of the pulse. Even shorter exposures are possible with grid-controlled tubes, and this makes them desirable for examinations requiring very short exposures. When a grid-controlled, short exposure is used, as in figure 1-39, the radiation dose to the patient is reduced. The reduction occurs because the exposure can be short enough so that it does not include the portions of the wave that only produce low energy photons. The patient's dose is also reduced when a grid-controlled tube is used with cinefluorography because X-ray production can be synchronized with the camera shutter. The synchronization reduces patient exposure because X-rays are only produced when the shutter is open.

Exercises (032):

In the exercises below, name two advantages of

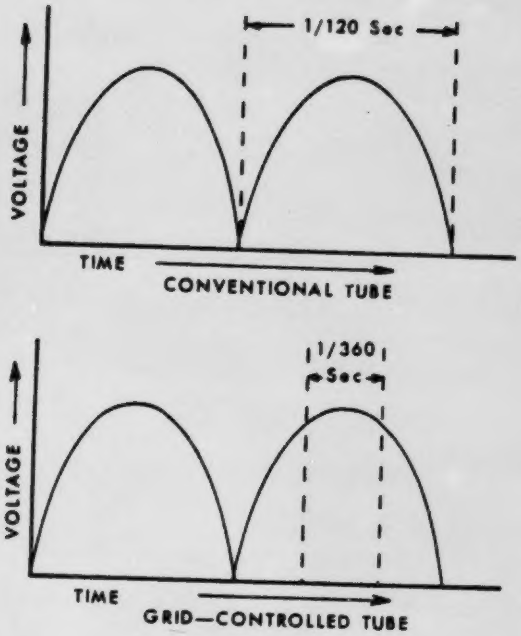


Figure 1-39. Comparison of exposure times between a conventional and grid-controlled tube.

using a grid-controlled X-ray tube and after each, explain why the advantage is realized.

1.

2.

033. Given selected exposure factors (mA, kVp, and sec), calculate the number of heat units per exposure.

Tube Rating Charts. How long will an X-ray tube last? Primarily, this depends on how well you take care of it. X-ray tubes are well constructed and provide years of useful service if properly used. When we say "properly used," we mean operated within the exposure limits that are established by the manufacturer and that are expressed in tube-rating charts. We will discuss several types of tube-rating charts and how to use them after we have reviewed the calculation of heat units.

Heat units. The maximum exposure limits for a particular tube are based on the amount of heat generated in the tube. This heat buildup is expressed in heat units (H.U.). H.U. are the product of kVp × mA × sec in single-phase generators. The formula is written

H.U. = kVp × mA × sec

For example, the number of H.U. generated by an exposure of 75 kVp, 100 mA, and 1/2 sec is 3,750 since:

H.U. = kVp × mA × sec
= 75 × 100 × 1/2
= 7,500 × 1/2
= 3,750

The number of H.U. generated by an exposure in a three-phase generator is found by multiplying the three previously mentioned exposure factors by 1.35. For example, to find the H.U., using 70 kVp, 100 mA, and 1/2 sec in a three-phase generator, proceed as follows:

H.U. = kVp × mA × sec × 1.35
= 70 × 100 × 1/2 × 1.35
= 3,500 × 1.35
= 4,725

Exercises (033):

1. How many H.U. are generated by a single-phase generator, using 200 mA, 80 kVp, and 1/10 sec?

2. How many H.U. are generated by a three-phase generator, using 300 mA, 1/20 sec, and 74kVp?

034. Given two different types of single-exposure, tube-rating charts, determine: (1) the maximum mA if the kVp and sec are given; (2) the maximum kVp if mA and sec are given; (3) the maximum sec if mA and kVp are given; and (4) whether or not three exposures are safe.

Single-exposure rating chart. One type of single-exposure, tube-rating chart is shown in figure 1-40. It is used to prevent damage to the tube from a single exposure and works as follows: Suppose you wish to use 100 kVp and 1/5 sec for an exposure and you want to find the maximum mA that can safely be used with those factors. Find where the 100 kVp line crosses the 1/5 sec line on the chart. From that point, move horizontally to the left and check the mA scale. In this case, it falls between 150 and 175 mA, which means the 150 mA station is the highest that can be used with 100 kVp and 1/5 sec. You can also find highest kVp or sec for a given exposure by using the same procedure.

You can also check an exposure against the chart to determine whether or not the exposure is safe. For example, suppose you wish to use 125 mA, 1 sec, and 100 kVp. Notice in figure 1-40 that 25 mA intersects the 100 kVp line slightly to the right of 1 sec (between 1 and 2 sec). This tells you that using these factors, an exposure time of a little more than 1 sec is permitted; therefore, the exposure is safe.

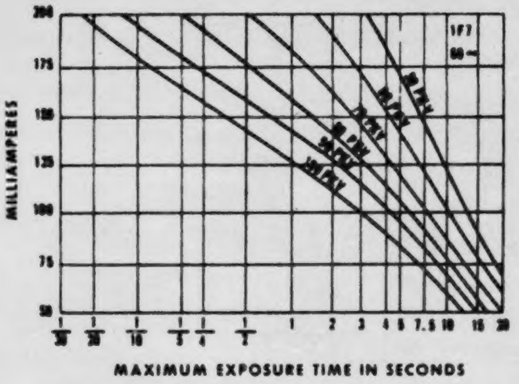


Figure 1-40. Single-exposure, tube-rating chart.

Another type of single-exposure, tube-rating chart is shown in figure 1-41. To find the maximum mA you can use, for example, 110 kVp (PKV on the chart) and 0.1 sec, simply find 110 kVp on the left margin. Move horizontally to the 0.1 sec column, and read the maximum mA, which in this case is 190. Use a similar procedure to determine the maximum kVp or exposure time and to determine whether or not an exposure is safe.

	EXPOSURE TIME IN SECONDS									
	UP TO 0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
PKV	MAXIMUM CURRENT IN MA										
50	220	220	220	220	220	220	220	220	220	220	170
60	270	270	270	270	270	270	270	270	230	190	150
70	320	320	300	290	290	270	250	230	190	160	130
80	270	270	260	260	250	240	220	200	170	145	110
90	240	240	230	230	220	210	200	180	150	130	100
100	210	210	210	200	200	190	180	160	140	115	90
110	190	190	190	190	180	170	160	150	125	105	80
125	170	170	170	160	160	150	145	130	110	90	72
150	145	145	140	140	135	130	120	110	95	75	60

Figure 1-41. Single-exposure, tube-rating chart.

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Exercises (034):

Complete exercises 1 through 4, which are based on the tube-rating chart in figure 1-42. (PKV on the chart is the same as kVp.)

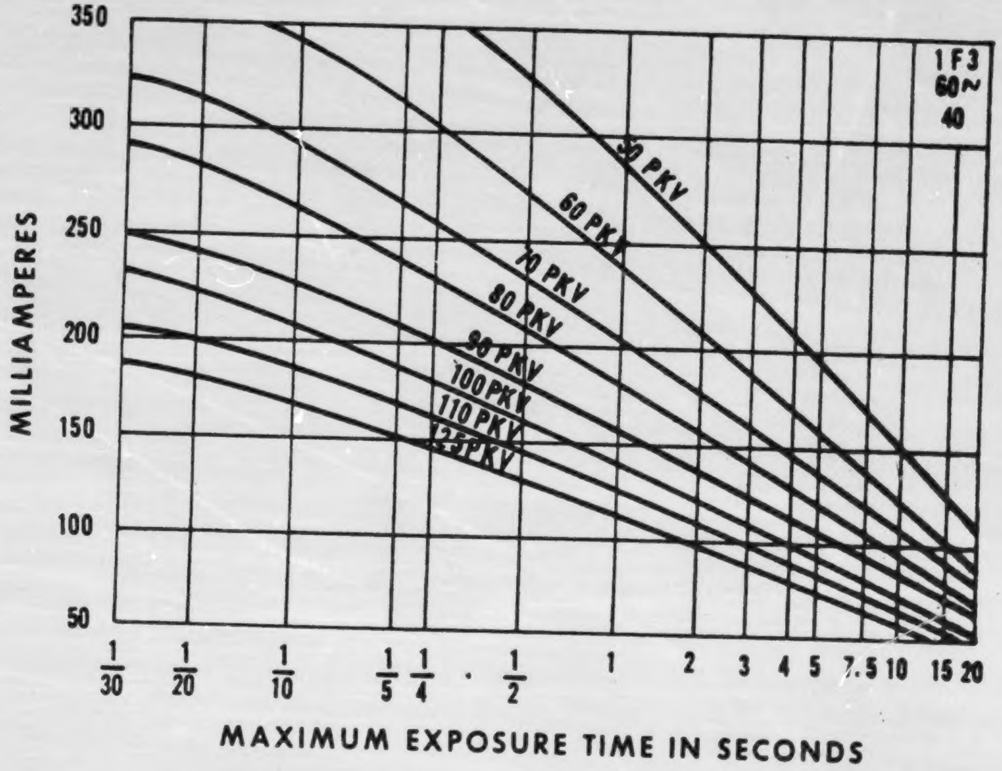

Figure 1-42. Objective 034, exercises 1 through 4.

1. What maximum mA station can safely be used with 1/4 sec and 90 kVp?

2. What maximum kVp can safely be used with 2 sec and 250 mA?

3. What maximum exposure time can safely be used with 200 mA and 110 kVp?

4. Are the following exposures safe?
   a. 200 mA, 70 kVp, 1 sec.
   b. 300 mA, 80 kVp, 1/30 sec.
   c. 100 mA, 100 kVp, 3 sec.

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Complete exercises 5 through 8, based on the tube-rating chart in figure 1-43. (PKV on the chart is the same as kVp.)

EXPOSURE TIME IN SECONDS

UP TO	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10	20
PKV	MAXIMUM CURRENT IN MA										
50	220	220	220	220	220	220	220	210	190	160	140
60	210	210	210	200	200	190	190	180	160	140	115
70	180	180	180	170	170	170	160	150	135	120	100
80	160	160	150	150	150	150	145	135	120	105	85
90	140	140	140	140	135	130	125	120	105	95	75
100	130	130	125	125	125	120	115	110	95	85	70
110	115	115	115	115	110	110	105	100	85	75	64
125	100	100	100	100	100	95	90	85	75	68	56
150	85	85	85	85	80	80	75	72	64	56	46

Figure 1-43. Objective 034, exercises 5 through 8.

5. What maximum mA can safely be used with 100 kVp and 2 sec?

6. What maximum kVp can safely be used with 0.01 sec and 100 mA?

7. What maximum exposure time can safely be used with 70 kVp and 180 mA?

8. Are the following exposures safe?
   a. 150 kVp, 0.2 sec, 100 mA.
   b. 60 kVp, 5 sec, 160 mA.
   c. 100 kVp, 0.01 sec, 160 mA.

035. Given an angiographic rating chart and various applicable exposure data, determine whether or not the exposures are safe.

Angiographic rating chart. Figure 1-44 is an example of an angiographic rating chart designed to allow you to determine whether or not the total number of exposures for an angiographic examination exceeds the maximum limits of the tube. Suppose your radiologist desires to perform an angiogram and wants two exposures per second for 2 seconds, a total of four exposures. The exposure factors are 1,000 mA, 1/10 sec, and 90 kVp. First, find the product of mA, sec, and kVp, which is 9,000. Find two exposures per second on the left margin of the chart; move across that column to 9,000 (the maximum load per exposure). Then move up to the total number of exposures, which in this case is two. This means that only two exposures can be made—so the examination cannot be performed under the described conditions.

TOTAL NUMBER OF EXPOSURES

EXPOS. PER SEC	2	5	10	20	30	40	50	60
	MAXIMUM LOAD IN PKV X MA X SEC PER EXPOSURE (*)							
1	16500	13800	11400	9000	7400	6400	5700	5000
2	9000	8000	7000	5700	5000	4400	4000	3700
3	6200	5600	5000	4300	3800	3400	3200	3000
4	4800	4400	3900	3400	3100	2850	2650	2500
5	3900	3600	3300	2900	2650	2450	2300	2150
6	3200	3000	2800	2500	2300	2150	2000	1900
8	2500	2350	2200	2000	1850	1750	1650	1550
10	2050	1900	1800	1650	1550	1460	1380	1320
12	1700	1600	1550	1420	1320	1260	1200	1160

Figure 1-44. Angiographic rating chart.

Exercises (035):

Using the angiographic rating chart in figure 1-45, determine whether or not each of the following groups of exposure data can be used for an angiogram.

	TOTAL NUMBER OF EXPOSURES							
	2	5	10	20	30	40	50	60
EXPOS. PER SEC	MAXIMUM LOAD IN PKV X MA X SEC PER EXPOSURE (*)							
1	10800	9600	8400	7000	6000	5300	4800	4400
2	5700	5200	4700	4100	3700	3400	3200	3000
3	3800	3600	3300	3000	2800	2600	2450	2300
4	2950	2800	2650	2400	2200	2100	2000	1900
5	2400	2300	2150	2000	1850	1750	1650	1600
6	2000	1900	1800	1700	1600	1500	1460	1400
8	1500	1460	1400	1320	1260	1200	1160	1120
10	1220	1180	1140	1080	1040	1000	960	940
12	1020	1000	960	920	880	840	820	800

Figure 1-45. Objective 035, exercises 1 through 3.

1. 300 mA, 1/30 sec, 120 kVp, eight exposures per second for 5 seconds.

2. 500 mA, 1/20 sec, 80 kVp, four exposures per second for 13 seconds.

3. 1000 mA, 1/10 sec, 96 kVp, one exposure per second for 6 seconds.

036. Given two cooling charts (anode and housing) and selected exposure data, answer key questions pertaining to: (1) the correlation between the charts and data and (2) the heat dissipation rate of the charts.

Cooling charts. There are two types of cooling charts: the anode-cooling chart and the housing-cooling chart. The anode chart shows the maximum number of H.U. the anode can store, and the housing chart shows the maximum number of H.U. the tube housing can store. Both charts also show the heat dissipation rate. Let's see how to use the charts, beginning with the anode-cooling chart.

Figure 1-46 shows an anode-cooling chart that can store a maximum of 300,000 H.U. (a relatively high capacity anode). Suppose that during an angiogram or a cine examination the total H.U. applied to the anode is 200,000, and it is necessary to repeat the examination without significant delay. If the examination were repeated immediately, there would be a total of 400,000 H.U. generated by the two examinations—100,000 H.U. more than the anode can store. In this case, to prevent damage to the tube, you would have to allow the anode to cool to 100,000 H.U. before the examination could be repeated. Find the cooling time between examinations by following the cooling curve from 200,000 H.U. to 100,000 H.U., which in figure 1-46 is about 5½ minutes. So this examination can be repeated every 5½ minutes.

The anode-cooling chart also tells you the relationship between fluoroscopic time and anode H.U. storage. For example, if the fluoroscopic kVp is 100 and the mA is 2, the H.U./sec input is 200. According to figure 1-46, 200 H.U./sec only subjects the anode to about 50,000 H.U. at the end of 15 minutes of continuous fluoroscopic time, allowing for the cooling that occurs during the 15 minutes. In figure 1-46, all of the H.U./sec inputs except 1,200 are safe for indefinite fluoroscopy because they do not subject the anode to the 300,000 H.U. maximum. The input of 1,200 H.U./sec, however, can only be used for 15 minutes because at that time, 300,000 H.U. are stored in the anode. Additional fluoroscopy can then be performed after an appropriate cooling time according to the cooling curve, as described earlier.

The housing-cooling chart, shown in figure 1-47, shows the maximum H.U. that can be stored in the tube housing. Notice that the tube housing stores more H.U. than the anode in figure 1-46 (both of these charts are for the same tube). Also, notice that the heat dissipation rate without the air circulator is considerably less than that of the anode in figure 1-46. To see the difference in the heat dissipation rate, notice that the anode in figure 1-46 dissipates

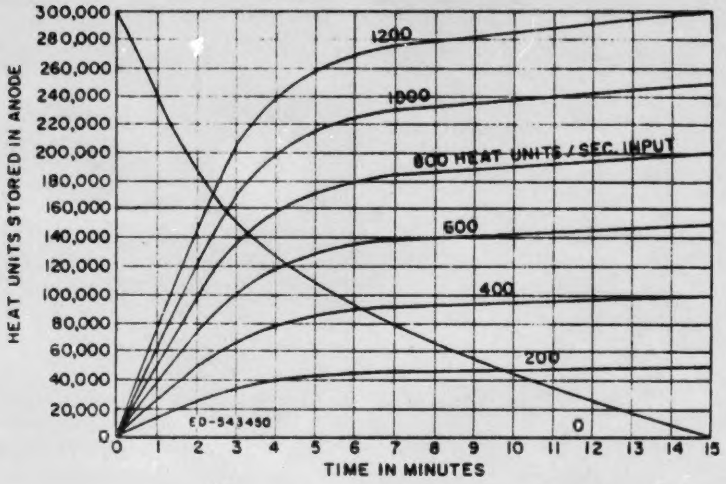

Figure 1-46. Anode cooling chart.

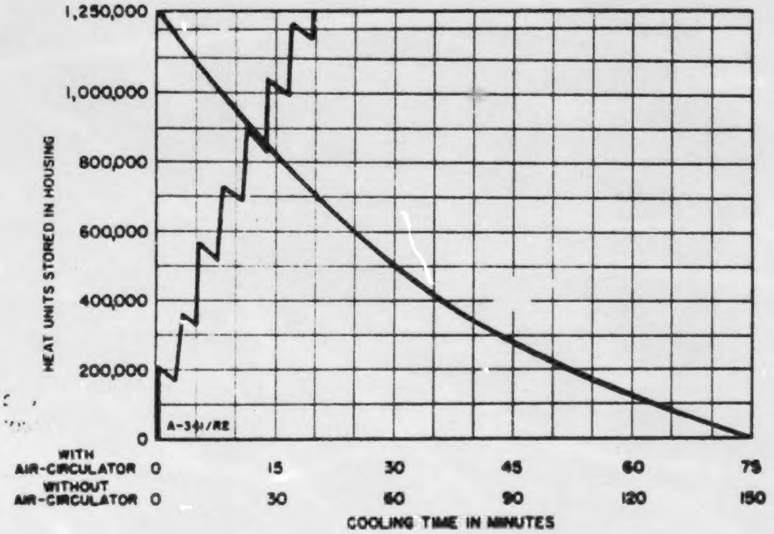

Figure 1-47. Housing cooling chart.

300,000 H.U. in 15 minutes, while the tube housing dissipates only about 200,000 H.U. in 15 minutes without the air circulator. This tells you that you can operate your tube safely within the limits of the anode-cooling chart; yet, you may exceed the maximum housing storage capacity. Let's look a little closer at such a situation.

Consider the 200,000 H.U. of the examination discussed earlier. We decided that the examination could be repeated every 5½ minutes without damage to the anode. If the examination were repeated several times, you would eventually reach the housing storage limit. Notice the zig-zag line in figure 1-47. Beginning in the lower left corner, the line goes vertically to 200,000 H.U. (the first examination). After 5½ minutes of cooling, based on the cooling curve, the stored H.U. drops to approximately 185,000 H.U. The next exam raises the stored H.U. to 375,000, and so on. Eventually, the stored H.U. in the tube housing reaches the maximum permissible. In this case, only about seven examinations could be performed consecutively.

Exercises (036):

Complete the following exercises based on the cooling charts in figure 1-48. Chart A is the anode cooling chart; chart B is the housing cooling chart. Both charts are for the same X-ray tube.

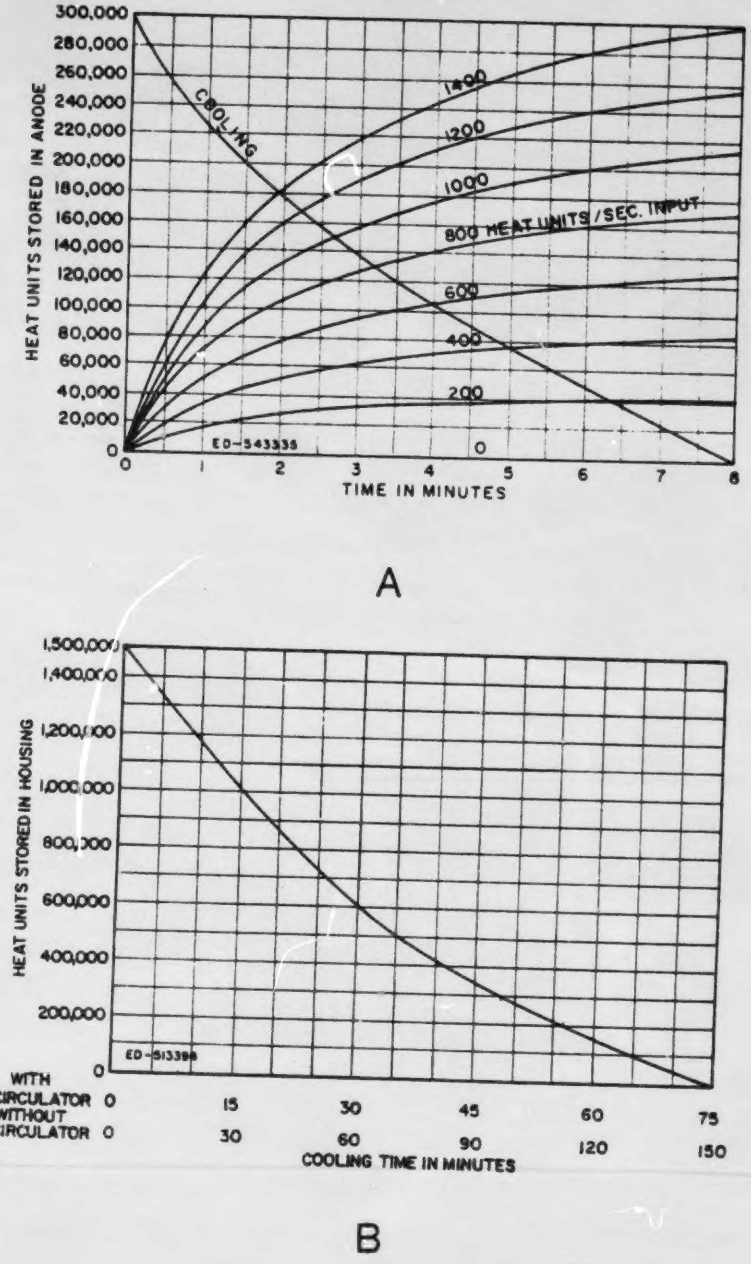

Figure 1-48. Objective 036, exercises 1 through 5

1. If you perform an examination that generates 140,000 H.U., how many minutes of cooling, if any, must you allow before repeating the examination once?

2. If you perform an examination that generates 220,000 H.U., how many minutes of cooling, if any, must you allow before repeating the examination?

3. How long can fluoroscopy be continuously performed, using 5 mA at 120 kVp?

4. How long can fluoroscopy be continuously performed, using an input of 1,400 H.U./sec?

5. If an examination generates 400,000 H.U., how many such examinations can be performed, if the minimum cooling time is allowed between examinations, before exceeding the housing storage capacity? The X-ray tube has no air circulator.

CHAPTER 2

The Primary Beam

QUALITY CONTROL is one cf the most important aspects of a well-coordinated, efficient radiology department. In this chapter we will discuss the principles that affect the use of X-radiation and that tie in directly with quality control. We will concentrate on a review of the primary beam and how it affects the radiographic image. By understanding these principles and characteristics, control of image quality becomes a reality. To achieve this objective, we will begin by discussing the characteristics of the primary beam. Principally important here are the elements called quality and quantity. Following the discussion of primary beam characteristics, you can apply your knowledge to the study of projection factors. These explanations will enable you to better understand how to formualte techniques and further improve quality control on the job.

2-1. Inherent Characteristics of the Primary Beam

The nature of the primary beam is evaluated by two factors, "quality" and "quantity." These are the terms by which you denote both penetrating ability and intensity of the X-ray beam. Let's begin our discussion with beam quality.

037. Given a list of statements pertaining to the quality of the primary beam, indicate which are true and which are false. If you indicate "false," explain your answer.

Quality. When we speak of the "quality" of the primary beam, we actually mean the ability of the beam to penetrate matter or, more specifically, human tissue. A high-quality beam is one with relatively high penetrating power, and a low-quality beam is one with low penetrating power. You should understand the penetrating power of the primary beam because a certain amount of X-ray photons must penetrate the part and reach the film to provide sufficient density and the desired degree of contrast. You can produce good diagnostic radiographs by using *more* penetration than is necessary, but if you use *less* than necessary, the radiograph will not be diagnostic. Consequently, we can say that for all practical purposes there is a minimum degree of penetration required for each body part. We cannot tell you precisely what the requirements are for each body part. They depend on several factors, including part size, pathology, and machine output.

"Wavelength" is another term associated with beam quality. The shorter the wavelengths of the X-ray photons, the greater the penetrating power. A beam of X-radiation is composed of many photons with varying wavelengths; hence it is a *heterogeneous* beam.

Since the *energy* of a photon is directly related to its wavelength, "energy" is yet another term closely associated with beam quality. The higher the energy of a photon, the shorter its wavelength. Keep in mind that although we may speak of the energy or wavelength of a single X-ray photon, there are millions of photons in a beam of X-radiation with different wavelengths or energies. Therefore, the *average* or *mean* energy, or wavelength, is the important factor.

How do you alter the quality of the primary beam? Obviously, by changing the kVp setting on your control panel. How does the kVp affect beam quality? If you increase the kVp on your control panel, you increase the energies of the electrons across the X-ray tube. Suppose you apply 80 kVp across the X-ray tube. Theoretically, the energies of the electrons range from 1 to 80 keV. (This range would be in a single-phase generator only. In a three-phase generator, the maximum electron energy would be the same, but the minimum energy would be higher, as discussed in Chapter 1.) The energies of the photons produced as the electrons interact with the target also range from 1 to 80 keV. Now suppose you apply 100 kVp across the X-ray tube. The electron energy range and the photon energy range increase proportionately. Consequently, the average energy of a beam of X-radiation is determined by the average energy of the electrons striking the target.

Exercises (037):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. Quality of the primary beam denotes penetrative ability.
T F 2. Good visualization of a body part occurs if the part absorbs all photons which strike it.
T F 3. Practically speaking, penetration of a part must meet or exceed a definite minimum.
T F 4. A highly energetic beam of X-radiation has relatively high-quality.
T F 5. Photons with long wavelengths have relatively low energy.
T F 6. The average energy of a beam of X-radiation depends upon the number of photons present.
T F 7. You can regulate the penetration ability of the primary beam by adjusting the kVp selector.
T F 8. An increase in kVp increases the minimum electron energy across the X-ray tube.
T F 9. If the average electron energy is lowered, the average photon energy is also lowered.

038. Define beam quantity and given a list of three factors affecting beam quantity, match the factors with appropriate definitive statements or phrases.

Quantity. The "quantity," or as it is usually called intensity, of a beam of X-radiation at a given FFO can be defined as "the characteristic which affects the density on a radiograph." Intensity of the primary beam is a measure of the number of photons per unit area in combination with the mean energy of the photons.

How do you control the intensity of the primary beam? To understand this, let's go back once again to the electrons which travel from the filament in the X-ray tube to the target. An increase in mA results in a higher filament temperature and more electrons available to traverse the tube for interaction. The more electrons interacting with the target, the more photons produced. Further, the increase in the number of photons is porportionate to the increase in the number of electrons. For example, if the number of electrons is increased, the number of photons, and consequently the intensity, is increased. Since mA, as discussed in Chapter 1, regulates the amount of electrons, you can see how adjusting the mA regulates the intensity of the primary beam.

Varying the exposure time is another way to regulate the number of electrons interacting with the target. Suppose 100 mA is applied to the X-ray tube for 1/10 sec. If the exposure time is increased to 1/5 sec, electrons are emitted from the filament at the same rate, but the period of time during which they are emitted is twice as long (1/5 ÷ 1/10 = 2). In effect, this change in the exposure time doubles the number of electrons interacting with the target and consequently doubles the number of photons produced.

Another way to control the intensity is with the kVp. While mA and exposure time control intensity by regulating the *number* of photons produced, kVp controls intensity by affecting the *number* of photons produced *and* by regulating the *mean energy* of the photons. As discussed earlier, if the kVp is increased, the energy of the electrons is increased. This increase in electron energy also increases the number of interactions and therefore increases the number of photons emitted from the target. A change of plus or minus 15 percent of the kVp amounts to the same change in intensity as doubling or halving the mA or exposure time.

As with the penetrating power of the beam, where we were not concerned with the energy of a particular electron, we are not concerned here with the specific number of photons. The relative intensity is the important issue.

Exercises (038):

1. In your own words, explain what is meant by beam quantity.

Match the quantity factor in column B with the appropriate statement or phrase in column A by placing the letter of the column B factor in the appropriate space in column A. Each column B factor may be used once, more than once, or not at all. In addition, more than one column B factor may match a single entry in column A.

Column A	*Column B*
___ 2. If doubled, this factor doubles the beam intensity.	a. mA. b. FFD.
___ 3. Affects both the number and energy level of the photons.	c. Exposure time. d. kVp.
___ 4. A 15 percent increase in this factor doubles the intensity.	
___ 5. Decreases intensity by decreasing the number of electrons available for interaction.	
___ 6. Affects intensity by affecting duration of electron emission.	
___ 7. Affects the number of electrons or photons per unit time.	
___ 8. Regulates beam quantity at a specific distance from the X-ray tube.	
___ 9. If halved, this factor halves the intensity.	

039. State the inverse square law, and show its effect on the intensity of the X-ray beam.

Inverse square law. In the preceding paragraphs we discussed beam intensity at a specific distance from the target. According to the *inverse square law* the intensity of the primary beam is not the same at various distances from the target of the X-ray tube. The *inverse square law* states that the *intensity of radiation in the primary beam is inversely proportional to the square of the distance from the target*. This means that as the distance from the tube increases, the intensity of the beam decreases. If the distance is doubled, the intensity decreases to one-fourth. By the same token, if the distance is halved, the intensity increases four times. This variation in intensity is a result of the divergence of the beam and can best be understood by referring to figure 2-1. Notice that the primary beam at 72 inches covers an area 4 times as great as at 36 inches because of its divergence. For comparative purposes, let's assume that the blocks in the figure measure 1 square inch, and the intensity at 36 inches is 20 X-ray photons per square inch, or 80 photons, for blocks 1, 2, 3, and 4. At 72 inches, because of the divergence of the beam, the 80 photons are now spread over 16 square inches, or 5 photons per square inch. Thus, the intensity is reduced to one-fourth at twice the distance. Note that when we discuss variations in intensity according to the inverse square law, we are only speaking of the number of photons. Photon energy does not enter into the picture.

Exercises (039):

1. State the inverse square law.

2. The intensity of the primary beam at 36 inches from the target is 200 photons per square inch. What is the intensity at 18 inches from the target? At 72 inches from the target?

3. Does the inverse square law affect beam intensity by affecting the number of photons emitted from the target? Explain your answer.

4. What is the connection, if any, between the inverse square law and photon energy?

040. Give the term used to describe the variation of intensity of the primary X-ray beam along the axis of the X-ray tube, and indicate the cause of this variation and the relationship between intensity and the distance from the central ray (CR).

Anode Heel Effect. The *anode heel effect* identifies the phenomenon which produces a variation in intensity of the radiation within the primary beam along the longitudinal axis of the X-ray tube. Using the CR as our starting point, let's see how the intensity varies.

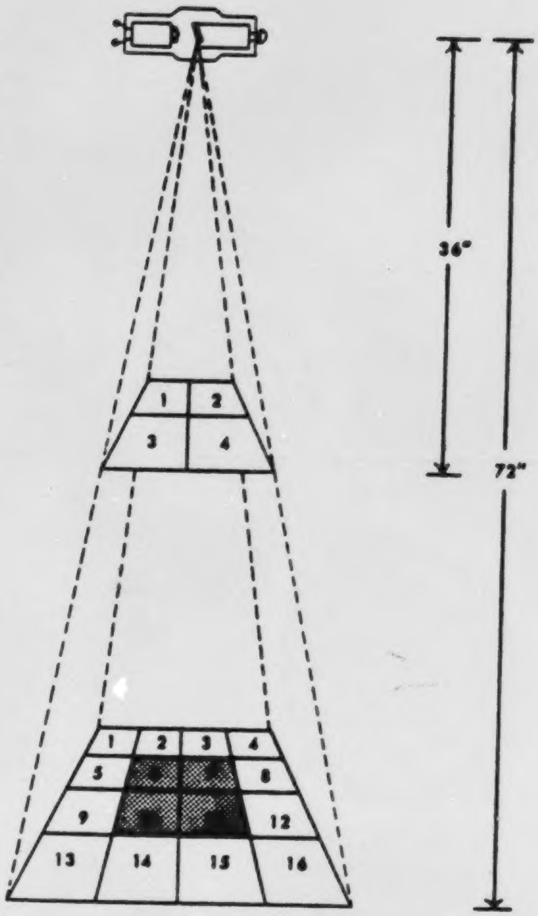

Figure 2-1. The primary beam and the inverse square law.

When we move away from the CR on the anode side, we find that the intensity becomes less and less the farther we go. Contrariwise, when we move away from the CR on the cathode side, we find the beam becoming more intense than it was in the CR area, or on the anode side. The area of increased intensity is limited, however, and, as we continue to move in the direction of the cathode, we find that the intensity again decreases. The intensity percentages at different angles of emission of a 20° anode are illustrated in figure 2-2. Keep in mind that the variation in intensity is only along the longitudinal axis of the X-ray tube. There is no variation along the transverse axis.

The variation in intensity is due to the angle of the anode. Some photons are emitted from within the target material, rather than from the target surface. As you can see in figure 2-3, photons emitted from within the target toward the anode side of the tube travel through more target material, and therefore, more of these photons are absorbed. On the other hand, since photons emitted toward the cathode side of the tube travel through less target material, fewer are absorbed by the target. Consequently, when we speak of the anode heel effect, we actually mean the number of photons per unit area as opposed to the energies of the photons.

Exercises (040):

Fill in the blank spaces below with the appropriate word or phrase pertaining to the anode heel effect of a 20° anode.

1. The variation in the intensity of the X-ray beam along the ________ axis of the X-ray tube is known as the ________ ________ ________.
2. The greatest variation in intensity occurs ________ from the CR.
3. The intensity of the primary beam gradually decreases toward the ________ side of the X-ray tube.
4. The intensity of the primary beam ________ toward the cathode side of the X-ray tube for a substantial distance and then begins to ________.

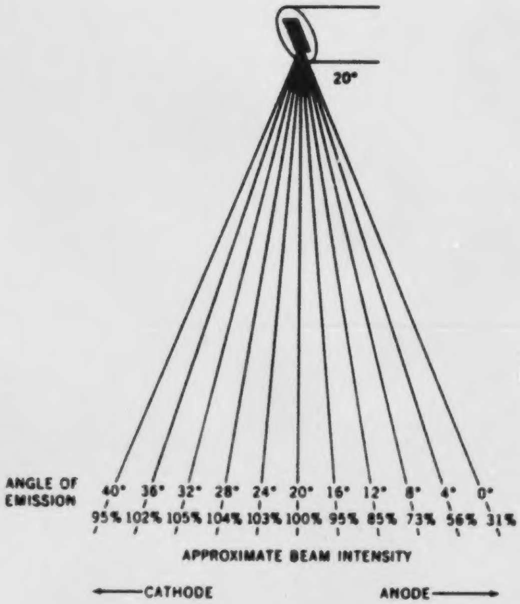

Figure 2-2. The anode heel effect showing how the intensity of the primary beam varies depending upon the angle of emission from the target.

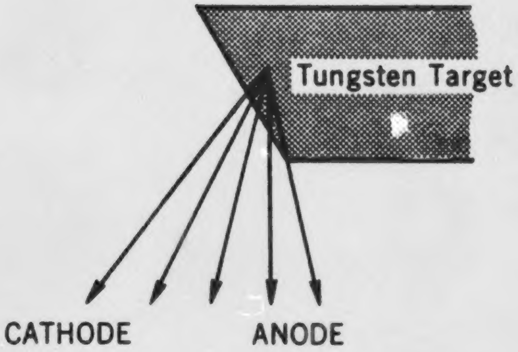

Figure 2-3. Illustration of a target showing how some photons travel through more target material than others.

5. The greatest concentration of X-ray photons is at a ________ angle off the surface of a 20° target.
6. More photons reach the film on the ________ side of the X-ray tube.
7. The anode heel effect is caused by ________ of X-ray photons by the ________ ________.

041. Given various hypothetical radiographic situations, apply anode heel effect to each situation.

Effect of tube angle. The intensity percentages of the primary beam vary with tubes having different target angles. Refer again to figure 2-2 and note that the percentage range for a 20° target is 95 percent to 31 percent. With a smaller target angle, of 10°, for example, there is a greater difference in the intensity; consequently, the anode heel effect is more pronounced.

Effect of FFD. Regardless of the target angle of your tube, one factor that you must consider along with the anode heel effect is the FFD. Consider figure 2-4. If part 1 is radiographed, the intensity range is 85 percent to 104 percent. If part 2 is radiographed, the intensity range is 31 percent to 95 percent. The former range is not sufficient to cause objectionable density variation on a radiograph, while the latter most certainly is. You can see the reason for the difference in the intensity percentage range if you will compare the total area of the primary beam required to radiograph each part in figure 2-4.

Effect of film size. Another factor to consider pertaining to the anode heel effect is the film size. Notice in figure 2-5 that if two different sized films are used, at a specific distance, the heel effect is more pronounced with the larger film. It follows from this discussion that radiographs of body parts requiring smaller films are less affected by the heel effect than radiographs of parts requiring larger films.

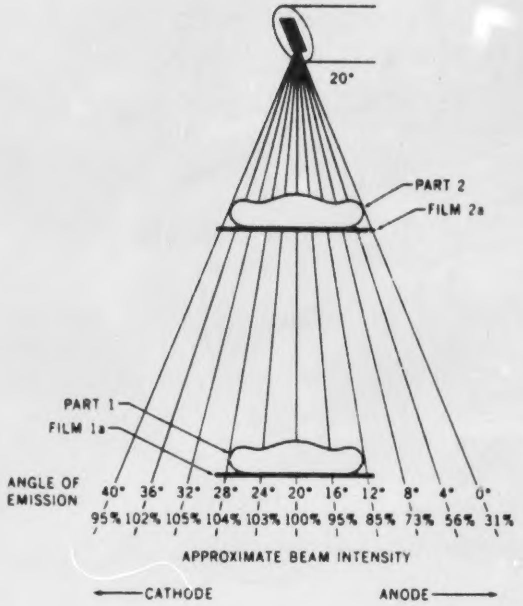

Figure 2-4. The anode heel effect showing how FFD affects intensity distribution.

Taking advantage of the anode heel effect. Although the anode heel effect at times can cause unbalanced density on a radiograph, it can be used to advantage when you X-ray certain parts of the body. Consider, for example, an AP thoracic spine. The thickness of the chest over the upper part of the spine is not as great as over the lower part. If you position the patient so that the anode side of the tube is over the upper spine and the cathode side over the lower spine, the anode heel effect will help to balance the uneven thicknesses. The leg and femur are two other parts requiring anode heel effect consideration.

Exercises (041):

You have three exposure rooms in your department. Room #1 has a target of 12° anode, room #2 has a 15° anode, and room #3 has a 17° anode. You must radiograph an AP thoracic spine on a patient whose lower chest is considerably thicker than average and whose upper chest is thinner than average. Based upon the information presented in the text, answer exercises 1 through 4 below.

1. Which exposure room would you use to take maximum advantage of the anode heel effect?

2. Why did you select that particular room? Be specific.

3. If the room you selected was tied up with a special procedure, which room would be your second choice?

4. How should the patient be positioned on the X-ray table with respect to the X-ray tube?

Your department has eight exposure rooms with anode angles ranging from 10° to 20°. You are establishing a room in which to perform all gallbladder examinations. A single examination consists of four spot-films (5" by 5" field). Based upon the anode heel effect considerations presented in the text, answer exercises 5 and 6 below.

5. Considering only the anode heel effect, which room would you select?

6. Explain the reason for your answer to exercise 5.

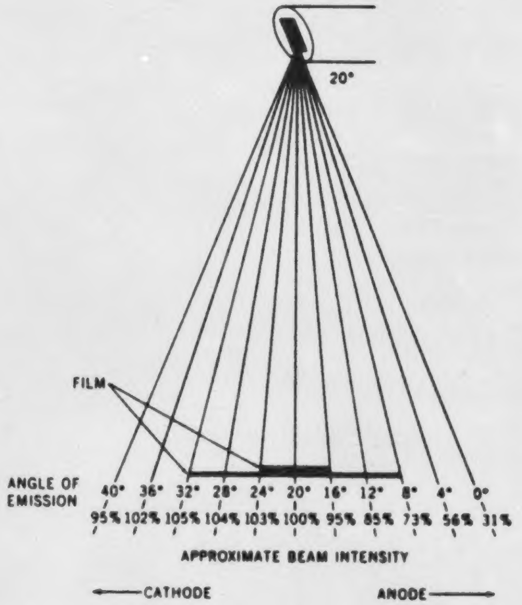

Figure 2-5. The anode heel effect showing how the intensity varies according to film size.

A portable AP radiograph is made of a leg using a 30-inch FFD and a 17° target. Later the same day another AP radiograph is made in the radiology department using a 40-inch FFD and also a 17° target. Based upon the information presented in the text, answer exercises 7 through 8 below.

7. How should the leg have been positioned to compensate for the difference between the size of the upper and lower portions?

8. Assuming the radiographs were made using the same relative exposure, which radiograph would show the greater difference between the densities of the upper and lower portions of the leg?

2-2. The Primary Beam and Its Projection of the Radiographic Image

We continue our study of the primary beam with the geometric factors that affect the quality of a radiographic image. Specifically, the factors are focal spot size and the relationships between the tube, part, and film. We will study these factors under the headings of focal spot size, magnification, and distortion.

042. Given a list of statements pertaining to the relationship between focal spot size and detail, indicate which are true and which are false. If you indicate "false," explain your answer.

Focal Spot Size. No doubt you have heard many times that you should use the smallest focal spot possible. You use the smallest focal spot to produce better detail on a radiograph and the "possible" means to use it when the exposure does not exceed the heat-loading capacity. We will deal with the heat capacity a little later. For now, let's look a little closer at the detail.

Focal spot size and detail. Why does a small focal spot produce better detail than a larger one? To answer that question refer to figure 2-6. Notice we have drawings of three focal spots projecting an image. Illustration A shows the focal spot as a point source of the X-ray photons. Illustration B represents a small focal spot, and illustration C represents a large focal spot. Notice we did not refer to the point source as a small focal spot because we have no focal spots that small in radiology. They usually range from 0.3 to 2.0 mm. We show the point source merely to illustrate the difference in the projection of the image.

Notice that all edges of the part in drawing A, figure 2-6, are projected to one spot on the film while in drawings B and C each edge is projected to a different spot. The reason each edge is projected to a different spot is that the edge is projected by photons from many points within the target. For simplicity, we have shown in figure 2-6 only the photons from each side of the target, which determine the maximum area of penumbra. When the border of a part is projected in this manner, it is called penumbra and has a "fuzzy" or "unsharp" appearance. The more penumbra present, the more unsharp the image, or we can also say the less the detail.

As you can see, there is less penumbra present on the image of the part projected by the smaller focal spot. A smaller focal spot causes less penumbra because the edges are projected by photons from fewer point sources.

Refer to figure 2-6, B and C, once again and notice the difference between the amount of penumbra from the anode side of the tube to the cathode side. As you can see, the amount is greater on the cathode side. What does this difference mean? First of all, it means that the edge of the part on the anode side is being radiographed with a smaller focal spot than the edge on the cathode side. Of course, the important aspect of this discussion is that radiographs have better (focal-spot) detail on the anode side. The farther toward the anode side, the better the detail; and the farther toward the cathode side, the worse the detail. Figure 2-7 gives you an idea of the relative focal spot sizes in the center and at both edges of the beam. The one in the center represents the size listed on your tube-rating chart.

Exercises (042):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. Better detail is obtained using a large focal spot.
T F 2. A large focal spot produces less penumbra.
T F 3. The more penumbra, the better the detail.
T F 4. Penumbra is greatest on the anode side of the tube.
T F 5. Radiographs have better detail on the anode side of the tube, due to the distance from the target.

043. Given hypothetical tube capacity data and situations requiring application of the data, apply the correct data to each situation and explain the reasons for your actions.

Focal spot size and heat-loading capacity. It would seem from the preceding discussion that you should always use the small focal spot on your X-ray machine. After all, it produces better detail, and detail on a radiograph is very important. However, there is a considerable difference between the heat-loading capacity of different-sized focal spots. A small focal spot will not tolerate high exposures; in fact, you would quickly damage your X-ray tube if you used the small focal spot for all exposures. Check the exposure factors against the tube-rating chart. If the rating chart shows the exposure to be within the maximum rating of the small focal spot, and if some other limiting factor, such as part motion, does not preclude use of the small focal spot—use it.

Exercises (043):

Suppose that the X-ray tubes in *your* two exposure rooms have the following focal spots. Further suppose that the *maximum* single exposure capacity is also as stated below.

Exposure room #1:
0.2 mm - 100 mA, 78 kVp, 1/4 sec
1.5 mm - 300 mA, 110 kVp, 1 1/2 sec

Exposure room #2:
0.5 mm - 200 mA, 80 kVp, 1/2 sec
2.0 mm - 500 mA, 120 kVp, 2 sec

1. Which exposure room could provide the least penumbra on a radiograph? The most?

2. Which focal spot(s) should you use to radiograph a lateral lumbar spine, using 100 mA at 110 kVp?

3. Suppose your radiologist asks you to establish procedures to perform a magnification radiograph of all wrists with a possible fractured navicular. He stresses the importance of keeping penumbra to a minimum. What action would you take, and why, concerning the exposure room and focal spot to use for the examination?

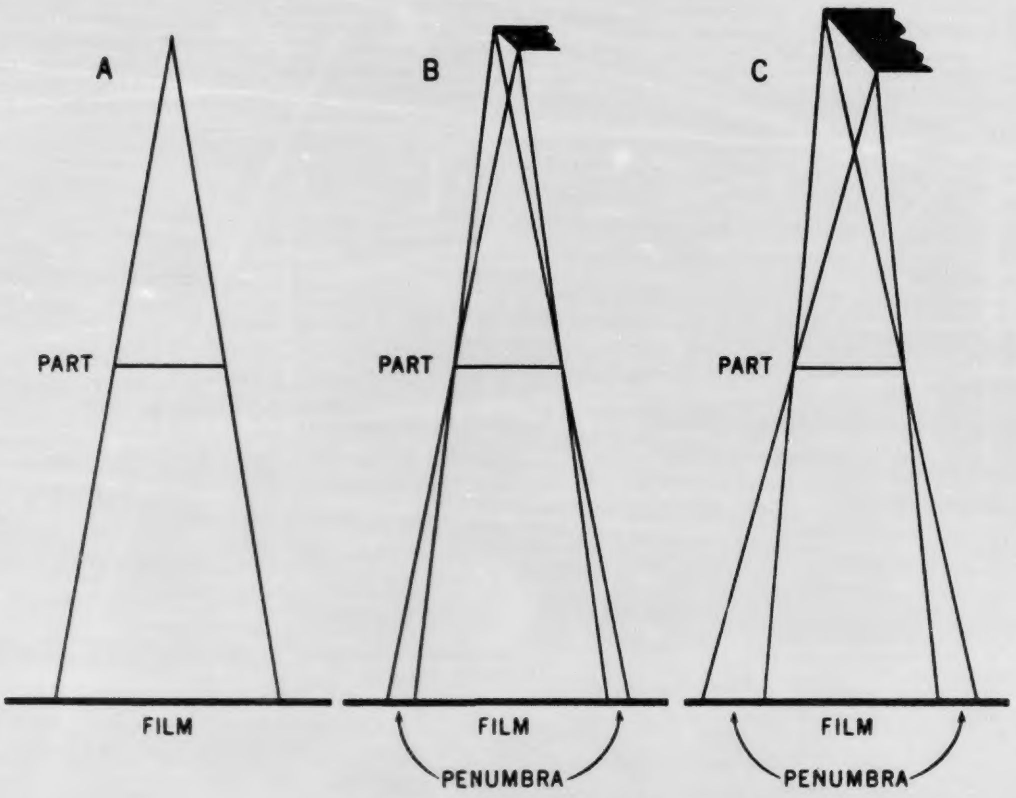

Figure 2-6. Projection of penumbra as a result of focal spot size.

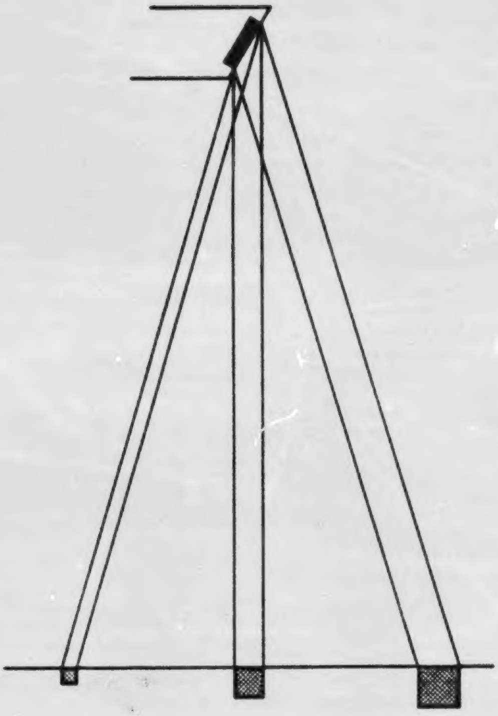

Figure 2-7. Focal spot sizes as seen from different parts of the X-ray field

044. Given selected descriptions of clinical radiographic situations, answer key questions concerning the effects of FFD and part-film distance upon the situations.

Magnification. Magnification should normally be kept to a minimum so that the part is projected as near as possible to its actual size. This is important to the radiologist's interpretation because increased magnification increases the penumbra on a radiograph, causing less clarity of the image. In addition, enlargement of some body parts is a sign of disease. If the part is magnified because of the projection, the radiologist may have difficulty making a diagnosis.

Factors affecting magnification. Basically two factors affect magnification: FFD and part-film distance. If you make two radiographs of a particular body part, using the same part-film distance and different FFDs, the radiograph with the longer FFD will show less magnification. To illustrate how FFD affects magnification, refer to figure 2-8, where we have illustrated the same size part projected by three different FFDs. Notice that a more divergent beam projects the part on the film at the short FFD. It is this greater divergence which increases the magnification.

Part-film distance also has a pronounced effect on magnification if the FFD remains constant. Notice in figure 2-9 that three parts of equal size are projected by the same FFD. The only difference is in the part-film distance. Part A, which is farther from the film, is magnified most, while parts B and C, which are nearer the film, are magnified progressively less. Magnification due to an increase in part-film distance occurs for the same basic reason as magnification from decreased FFD—that is, the part is projected by a more divergent beam.

Practical applications of FFD and part-film distance. As you know, the FFDs used in your department under routine conditions are established by your radiologist. Also, the part-film

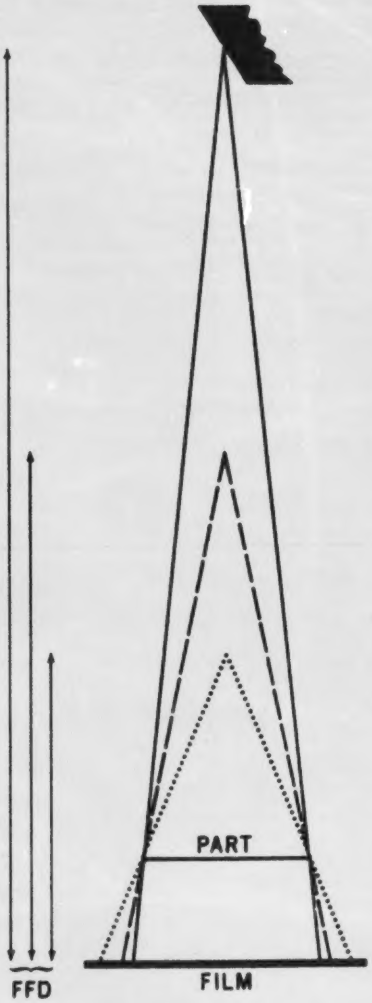

Figure 2-8. How a variation in FFD affects magnification on a radiograph.

distance is usually dictated by the particular projection, also established by your radiologist. So why should you even be concerned with the FFD and part-film distance? Let's examine some conditions other than routine and see.

Suppose you are the quality control technician and see a skull series performed on a patient with a possible fracture of the superior portion of the right temporal bone. The only lateral radiograph included is a left lateral. From our previous discussion, you should realize that the left lateral does not show the right side as well as does a right lateral. The reason—there is more part-film distance, resulting in less detail of the right temporal bone. Of course, there may be a good reason why the right lateral was omitted—such as an uncooperative patient. However, you won't know that until you investigate, will you?

Let's look at another condition. A patient with some sort of traction device on his leg is X-rayed. The device adds 2 inches to the part-film distance for the AP projection. There is an obvious fracture of the midshafts of the tibia and fibula and a questionable fracture involving the ankle joint. Your radiologist wants another AP projection with more detail to reevaluate the suspected joint fracture. What would you recommend to the specialist to satisfy the radiologist's request? While there are a number of factors that could be considered—such as a smaller focal spot, slower screens, and direct exposure—you shouldn't overlook the FFD.

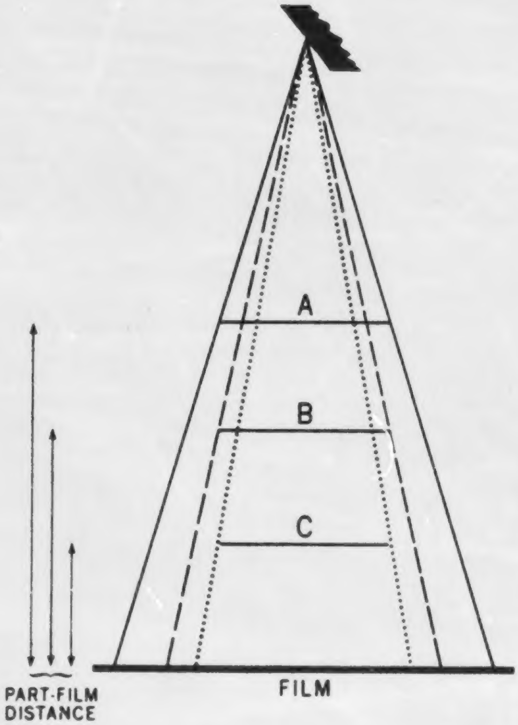

Figure 2-9. Illustration of the effect of part-film distance on magnification if the FFD remains constant.

Exercises (044):

1. If a patient is suspected of having a linear fracture of the right parietal bone, which lateral of the skull would best demonstrate the fracture? Why?

Two PA radiographs of the chest are made of the same patient. Radiograph A using a 60-inch FFD and radiograph B using a 72-inch FFD. All of the factors are equal. Based on the information in the text, answer exercises 2 through 7 below.

2. If the radiographs were made for suspected heart enlargement, which one is best?

3. Which ribs (anterior or posterior), on which radiograph, will have greater magnification?

4. Which radiograph will have better overall detail?

5. If a properly positioned lateral projection of the right temporomandibular joint shows the detail of the left side of the skull interfering with visualization of the joint under study, how could you alter the FFD to decrease the detail of the left side?

6. The clinical history on the patient's X-ray request states "pneumonia, right lower lobe." A chest X-ray is ordered. A student specialist asks you what lateral projection to take. What do you tell him and why?

7. Due to conditions beyond his control, a student specialist performs a portable radiograph of a femur with more than normal part-film distance. There is too much penumbra on the radiograph. What FFD change could you recommend to decrease the penumbra? Why?

045. Answer key questions pertaining to radiographic distortion.

Distortion. A part is said to be distorted when it is not projected on the film in its true shape. As a general rule, you should try to keep distortion to a minimum on your radiographs so that the part will appear in its normal shape. Thus, the radiologist can more easily recognize an abnormality. However, at times, deliberate distortion is necessary to project a part away from superimposed structures, as we will discuss later in this section.

CR-part-film relationships. The relationships between the CR, the plane of the part, and the plane of the film affect distortion. Specifically, the plane of the part and the plane of the film must be parallel, and the CR must be perpendicular to minimize distortion. Notice in figure 2-10 the radiographs of a 2- by 2-inch square. Radiograph A was made under the above conditions. Radiograph B was made with the CR angled 40°. The plane of the square and film were parallel. Radiograph C was made with the square angled 40°. The CR was perpendicular to the film. Radiograph D was made with the film angled 40°. The CR was perpendicular to the square. As you can see, the shape of the square varies. This should indicate to you the importance of the CR-part-film relationship. Incidentally, the square had two "fractures." Can you see them on all projections?

Acceptable distortion. There are times when distortion is permissible, even necessary. As example is the inferosuperior or axial projection of the clavicle. Distortion is necessary in this case to demonstrate the clavicle free from superimposition of the ribs.

Exercises (045):

1. What is the general rule regarding distortion on a radiograph?

2. Is distortion ever acceptable? Explain your answer.

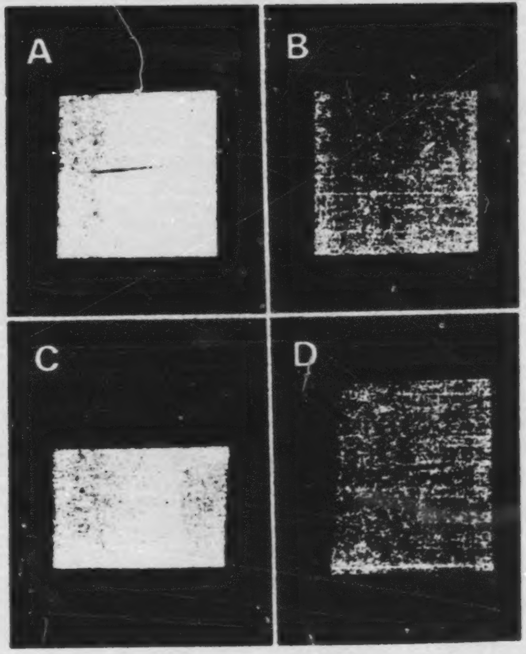

Figure 2-10. Radiographs of a radiopaque 2- by 2-inch square showing how tube angle and nonparallel part and film cause distortion on a radiograph.

3. How should the CR be directed, with respect to the part and film, to prevent distortion?

4. If the long axis of the femur is placed at a 35° angle to the plane of the film and the CR is perpendicular to the film, would the femur be distorted on the radiograph?

5. What relationship must exist between the part and film to prevent distortion?

CHAPTER 3

Exposure Devices

EARLY IN THE history of radiography, the pioneers in the field became aware of a serious problem affecting film exposures. The problem was film fog due to scatter radiation. To overcome this condition, certain devices were developed, which are referred to as exposure devices. Initially and until a few years ago, cones, cylinders, and diaphragms were used extensively to restrict the beam of X-radiation and thereby reduce film fog. However, these devices have more or less given way to collimators—the topic of the first section of this chapter.

Another important exposure device used to reduce film fog is the grid. Many refinements have been made in grids since they were introduced. For example, it is no longer sufficient for a technician, to merely know that a grid reduces scatter radiation. Some grids reduce scatter better than others and the kVp range even affects scatter "clean-up" to a certain extent. We begin our discussion of exposure with collimators.

3-1. Collimators

046. Given a list of statements pertaining to the functions of a collimator, indicate which are true and which are false. If you indicate "false," explain your answer.

Functions of a Collimator. A collimator beam-restricting device is used for precisely that purpose—to restrict the size of the primary beam. As you know, you should *always* restrict the size of the primary beam to the smallest size possible and still include the part under study in the X-ray field. If you think you have heard that last statement before, no doubt you have, and you will hear it again and again. Using a small X-ray field is important for two reasons: (1) it reduces the exposure to the patient and (2) it reduces film fog due to scatter radiation. (We will discuss beam size and patient exposure in Chapter 6.)

One of the major causes of film fog is scatter radiation that reaches the film. The amount of scatter radiation produced by an X-ray beam is related to the size of the X-ray field. Refer to figure 3-1, where we have illustrated the same body part projected by both a large and a small X-ray field. For a part of this size, we need only a relatively small film area. If the primary beam is restricted to only that portion of the X-ray film needed, as in drawing A, you can see that there is a certain amount of scatter radiation reaching the film. However, if the beam is enlarged so that it covers a larger area, as seen in drawing B, there is an increase in the scatter radiation reaching the film. Notice that the increase in scatter reaching the film not only occurs on the parts of the film that do not record the image, but it also occurs directly over the image itself. The reason for this is that some scatter radiation is emitted at acute angles with respect to the film.

There are many applications of a small cone field. Let's look at one examination and see how a small cone field may affect the outcome. Suppose the part shown in figure 3-1 is a gallbladder. Further suppose that the concentration of contrast medium in the gallbladder is less than it should be for one reason or another. Because of the minimal concentration of the contrast medium, there is little contrast between the gallbladder and the surrounding structures. If you use a large cone field, you further reduce the contrast by increasing the film fog. But if you use a small cone field, contrast is increased—perhaps enough to adequately demonstrate the gallbladder. The difference in contrast could be sufficient to permit diagnosis of, for example, gallbladder stones. Otherwise, the patient may have to be rescheduled for another examination.

Exercises (046):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. A beam-restricting device reduces the intensity of the primary beam.
T F 2. You should use the smallest size X-ray field consistent with the requirements of the examination.
T F 3. A small X-ray field reduces patient exposure.
T F 4. A small X-ray field increases contrast.
T F 5. You can reduce scatter radiation by using a larger X-ray field.

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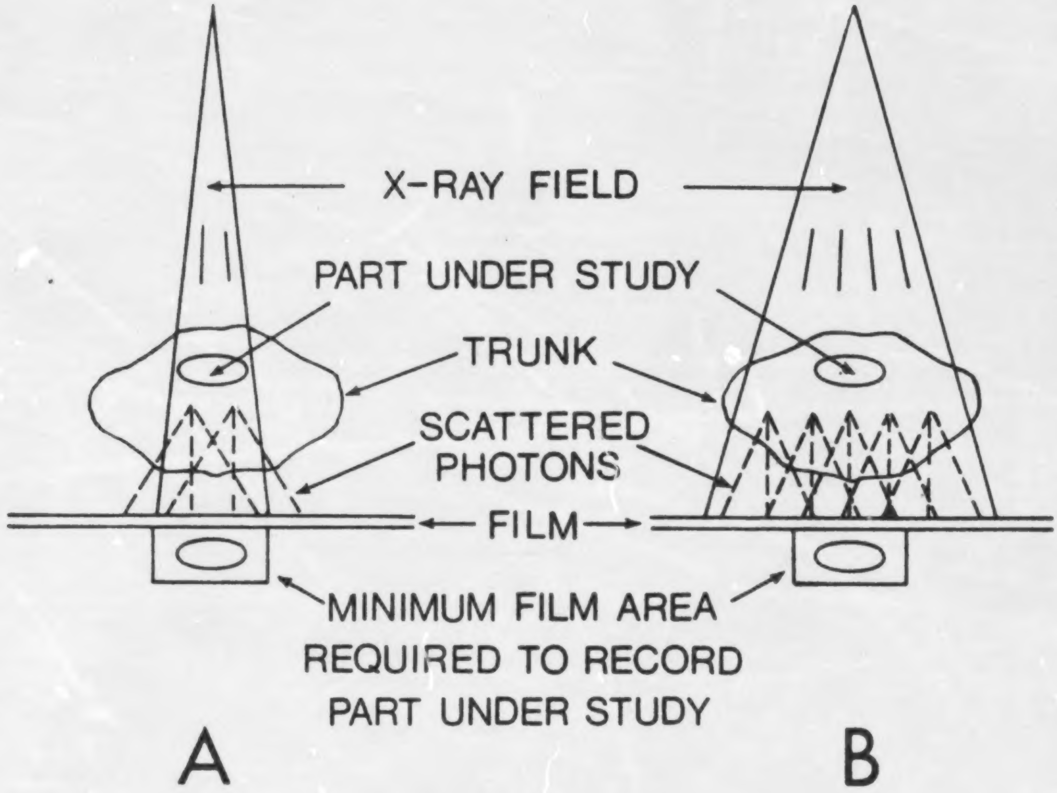

Figure 3-1. Effects of small and large X-ray fields on scattered radiation.

T F 6. A small X-ray field produces less film fog than does a large one.

T F 7. Scatter radiation from a specific area within the body can fog the film in more than one spot.

047. Describe the procedure for checking the accuracy of the numerical collimator scale; and given appropriate data, determine if four collimator scales meet prescribed standards.

Collimator Requirements. AFM 161-38, *Diagnostic X-Ray, Therapeutic X-Ray, and Gamma-Beam Protection for Energies Up To 10 Million Electron Volts,* requires that multipurpose X-ray units be equipped with an adjustable rectangular collimator containing a light localizer that defines the entire X-ray field. This means that all of your X-ray machines, except for special-purpose units, such as used for mammography, must have such a collimator. The manual also describes several specific collimator requirements.

Numerical scale. According to the manual, a numerical scale must indicate the size of the X-ray field at specific distances from the target. The scale must be accurate within 2 percent of the FFD when the CR is directed perpendicularly to the plane of the film. This means that if, for example, you set the collimator scale for a 10- by 10-inch X-ray field at a 40-inch FFD, the actual X-ray field must be within 2 percent of 40. The 2 percent refers to the sides of the X-ray field. In the case cited above, each border of the X-ray field must measure from 9.2 inches to 10.8 inches (2 percent of 40 is 0.8).

It is a simple matter to check the accuracy of the numerical scale. All you have to do is to set the scale for a certain size field at a specific FFD and make an exposure on a film at that FFD. Then measure the sides of the X-ray field. Adjustments to the collimator should be made by your medical equipment repairman.

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Exercises (047):

1. In your own words, describe the procedure for checking the accuracy of a collimator numerical scale.

Figure 3-2 shows drawings of four X-ray fields made to check the accuracy of four collimator scales. The scale setting for each drawing is indicated opposite exercises 2 through 5 below. Indicate opposite the exercises below whether or not the collimator meets the prescribed standards in each case.

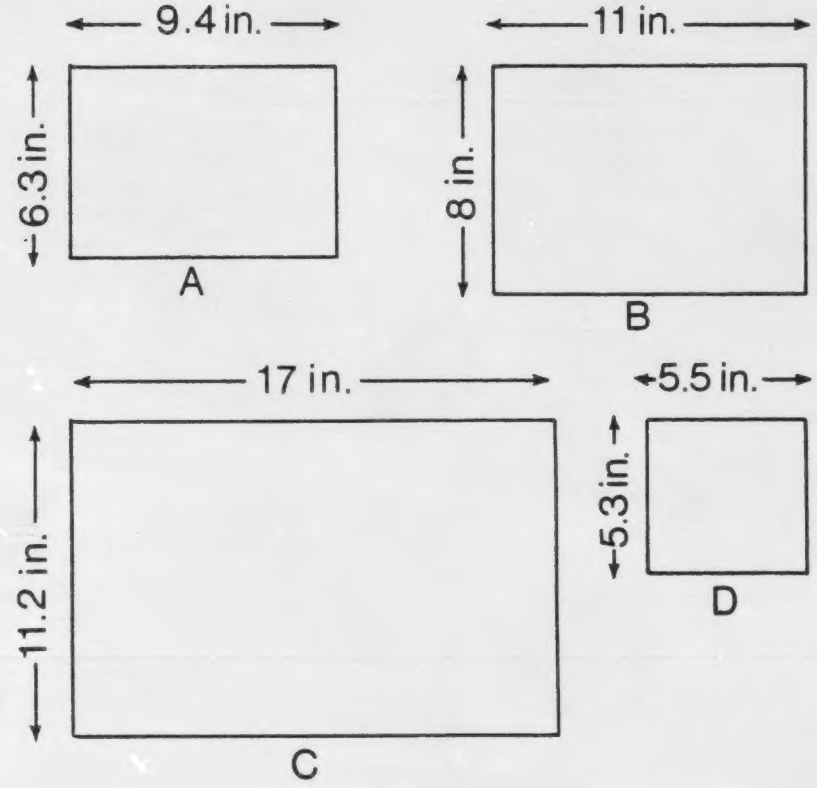

Figure 3-2. Objective 047, exercises 2 through 5.

2. Figure 3-2,A—scale set for a 7- by 9-inch field at a 40-inch FFD.

3. Figure 3-2,B—scale set for a 9- by 11-inch field at a 40-inch FFD.

4. Figure 3-2,C—scale set for a 13- by 16-inch field at a 72-inch FFD.

5. Figure 3-2,D—scale set for a 6- by 6-inch field at a 30-inch FFD.

048. Explain the performance of the beam-defining light and X-ray field compatibility test in terms of wire placement, exposures, collimator adjustment, and compatibility measurements; and evaluate specific test data.

Beam-defining light versus X-ray field. The previously mentioned manual also requires that the "lighted" X-ray field be aligned with the "actual" X-ray field within 2 percent of the FFD. This requirement is also based upon a CR perpendicular to the plane of the film. For example, if the lighted field measures 8 by 10 inches, the short side of the X-ray field must measure between 7.2 and 8.8 inches, and the long side must measure between 9.2 and 10.8 inches.

To check the X-ray field against the lighted field, place a cassette on the table and turn the collimator light on. Adjust the collimator until the lighted field is at least 2 or 3 inches smaller than the film. Place four small pieces of wire, each bent to form a 90° angle, so that the angles correspond to the corners of the lighted field. Measure the borders of the lighted field and record the information. Place some sort of orientation marker on the film so that you can identify the side(s) of the collimator that is out of adjustment. Make one exposure; then open the collimator to cover the entire film and make another exposure. After processing, measure the sides of the X-ray field and compare them to the measurements of the lighted field. If any side of the X-ray field deviates by more than 2 percent of the FFD, the collimator must be adjusted.

Figure 3-3 is a drawing of a test radiograph. This drawing shows one side of the collimator, AB (the side near the back of the table if the "R" was placed in the near right-hand corner of the lighted field), to be out of adjustment. Sides AC and BD of the X-ray field are shorter than the corresponding light field sides. Whether the collimator meets the required standards depends upon whether sides AC and BD are off more than 2 percent of the FFD. Also notice that the "wires" near corners A and B would not have been seen on the radiograph if the second exposure had not been made.

Exercises (048):

Answer the following questions based on the collimator light, X-ray field compatibility test.

1. How are the wire pieces placed on the cassette?

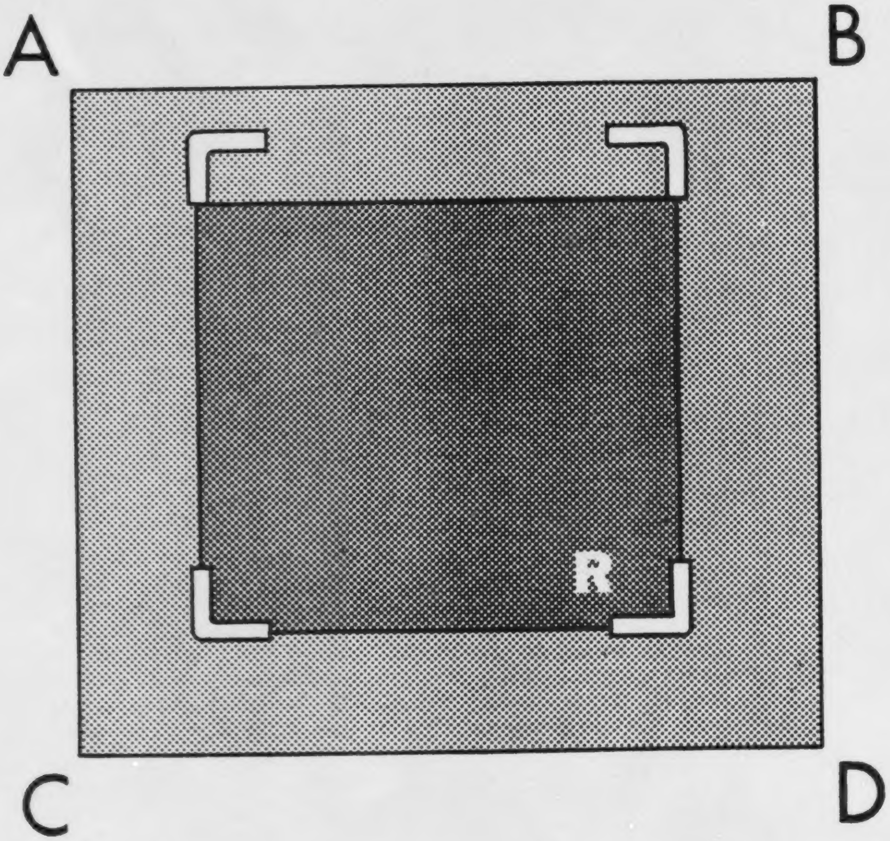

Figure 3-3. Drawing of a radiograph made to check the X-ray field against the lighted field of a collimator.

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2. How many exposures should you make?

3. Why is the second exposure made?

4. When making the test radiograph, how can you be assured of identifying the sides of the collimator requiring adjustment?

5. What measurements of the test radiograph should you make to determine the compatibility?

In exercises 6 through 9 below, evaluate the test data and determine if the collimator meets prescribed standards.

6. Lighted field size—8 by 10 inches at 40 inches FFD, X-ray field size—7 by 10 inches.
7. Lighted field size—10 by 10 inches at 40 inches FFD, X-ray field size—10 by 10.4 inches.
8. Lighted field size—4 by 5 inches at 25 inches FFD, X-ray field size—3.6 by 5.4 inches.
9. Lighted field size—14 by 17 inches at 72 inches FFD, X-ray field size—12.2 by 17 inches.

3-2. Grids

While the use of a collimator contributes substantially to the reduction of film fog, it by no means solves the problem completely. Considerable film fog still occurs unless an additional device is used.

049. State the purpose, operation, and application of a grid; indicate whether or not a grid should be used with specific body parts.

Function and Operation of a Grid. The purpose of a grid is to reduce film fog by reducing the scatter radiation that would otherwise reach the film. As you know, the grid is placed between the part and film. Scatter radiation is emitted from many points and in many directions from the patient. Because the greatest portion of the scattered rays strike the lead strips at an angle, most of them are absorbed. Most of the primary radiation, on the other hand, is transmitted by the grid because the individual photons approach the grid from angles corresponding to the angles of the lead strips. Figure 3-4 shows the relationships between the angles of the lead strips and the direction from which primary and scattered radiation approach the lead strips. Since some body parts do not emit enough scattered radiation to significantly fog a radiograph, they should not be radiographed with a grid. As a general rule, we can say that parts 11 centimeters thick and below can be taken without a grid. Some radiologists, however, prefer that a grid be used with parts over 9 centimeters thick. The one exception is the chest radiograph; it may be taken with, or without, a grid.

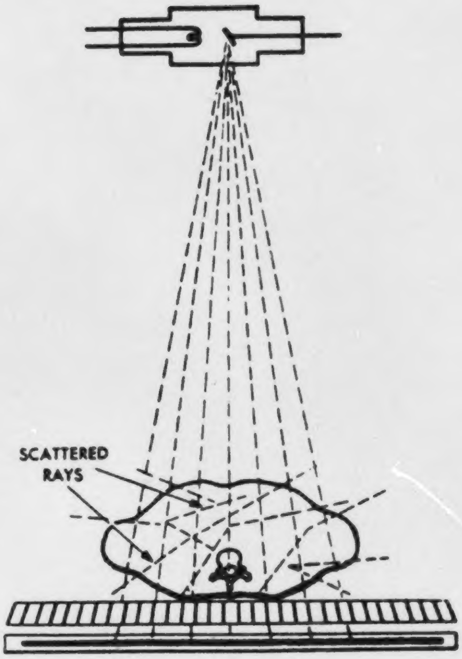

Figure 3-4. Relationships between primary radiation, scattered radiation, and grid strips.

Exercises (049):

1. How does a grid reduce film fog?

2. Does a grid absorb all of the scattered radiation?

3. Are all of the primary X-ray photons transmitted through the grid?

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4. Why is absorption of scattered radiation by a grid greater than its absorption of primary radiation?

Match the normal grid application in column B with the appropriate body part in column A by placing the letter of the column B item beside the number of the column A item. Each application may be used once or more than once.

Column A

___ 5. Skull.
___ 6. Wrist.
___ 7. Lumbar spine.
___ 8. Pelvis.
___ 9. Elbow.
___ 10. Os calcis.
___ 11. Chest.

Column B

a. Grid.
b. Nongrid.
c. Either grid or nongrid.

050. Differentiate between grid ratio and grid radius.

Grid Design. There are many different grids on the market today. Some are designed to be used under specific conditions. In order for you to use the grid that best fits your particular needs, it is necessary to be aware of the elements of grid design.

Grid ratio. The height of a lead strip in relation to the width of the space between two strips is called the grid *ratio* (see fig. 3-5). Ratio is not directly related to the thickness of the grid or to the number of lines (lead strips) per inch. Consequently, a thin and a thick grid can have the same ratio, and an 80-line grid can have the same ratio as a 100-line grid.

Each grid has a specified ratio, and it can usually be found on the tube side of the grid. Common grid ratios are 4:1, 5:1, 8:1, 12:1, and 16:1. Grid ratio is important to you because it affects not only the efficiency of the grid but also the tube alignment.

Grid radius. In some grids, the lead strips are parallel to each other; such a grid is called a parallel or unfocused grid. In others, the lead strips are angled; these grids are said to be focused:

a. In an unfocused grid, if imaginary lines parallel to the lateral surfaces of the strips were extended, they would never meet. In other words, there is no point at which the imaginary lines would come together. Figure 3-6 represents an unfocused grid. Note that all the strips are perpendicular to the plane of the grid and that the lead strips are parallel with each other.

b. When the lead strips in the grid are inclined at progressively larger angles farther from the center strip, the grid is said to be focused. A focused grid has a grid *radius* which is the distance from the center of the grid to a point where the planes of the lead strips would meet. Figure 3-7 shows a cross-section of a focused grid, and figure 3-8 shows the grid radius.

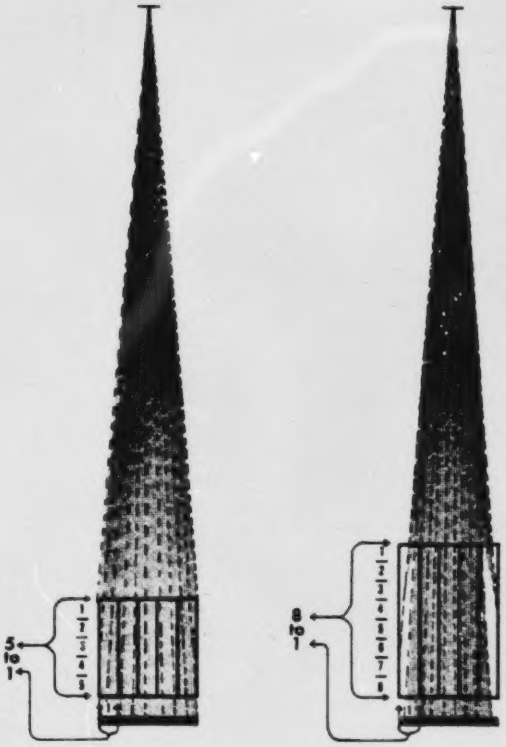


Figure 3-5. Examples of grid ratios.

The grid radius is important to you because it affects your FFD. A grid usually has a radius specified on its tube side—although on some grids the FFD range is specified instead of the ratio.

Exercises (050):

Match the grid design characteristic in column B with the appropriate statement in column A by placing the letter of the column B item in the appropriate space in column A. Each column B item may be used once or more than once. In addition, both column B items may match a single column A statement.

Column A

___ 1. Affects grid efficiency.
___ 2. A focused grid has one.
___ 3. An unfocused grid has one.
___ 4. A specified distance.
___ 5. Affects FFD.
___ 6. Affects tube alignment.
___ 7. Pertains to height of a lead strip and interspace.
___ 8. Lead strips are not parallel.

Column B

a. Grid ratio.
b. Grid radius.

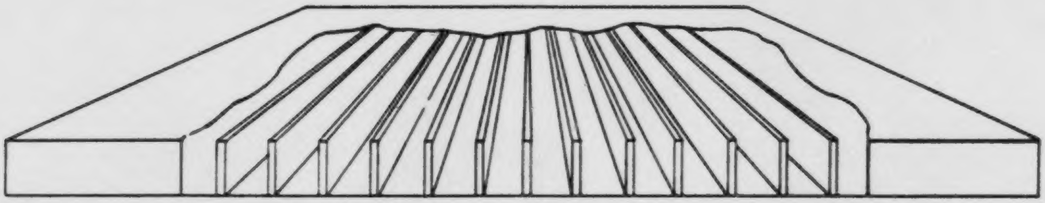


Figure 3-6. Cutaway of an unfocused grid.

051. Explain how the number of lines per inch in a grid affects the appearance of a radiograph.

Lines per inch. Grids are available with various numbers of lines per inch. For example, a 12:1 grid is made with 80 or 100 lines per inch. One difference between the 2 is that the 100-line grid is thinner than the 80-line. The greatest advantage of a grid with many lines per inch is that the lead strips are less visible on the radiograph and therefore interfere less with interpretation. This, of course, is based on the assumption that the grid is not moved during exposure. The reason the strips are less visible is that, for a given ratio, more lines per inch means that the lead strips are thinner and are not as high. This change in the size of the lead strips reduces the total lead content of the grid. Consequently, for a given ratio, a grid with many lines per inch improves contrast less than one with few lines per inch. The reason the one with many lines per inch does not improve contrast as much is that less scattered radiation is absorbed.

Exercises (051):

1. If two radiographs of the same part are made, one using 8:1, 80-line, and the other using 8:1, 100-line, stationary grids, on which radiograph would the lead strips be more visible? Why?

2. How does the number of lines per inch of a grid affect radiograph contrast? Why?

052. Differentiate between the construction and the uses of a linear and a crossed grid.

Arrangement of lead strips. Grids are made with the lead strips in either a linear or a crossed pattern:

a. A linear grid is one with all the lead strips running parallel with each other. Most grids in X-ray tables are linear, and the strips always run longitudinally. Linear grids are also available in grid-cassettes and as regular portable grids. The directions of the lead strips with respect to the longitudinal axis of the X-ray table, grid-cassette, and portable grid are shown in figure 3-9.

b. A crossed grid is made with two sets of lead strips arranged as shown in figure 3-10. Crossed grids are usually not found in X-ray tables used for general radiographic work.

c. There are certain advantages and disadvantages of using both linear and crossed grids. A linear grid permits virtually unlimited tube angles—if the angle is in a direction parallel to the length of the strips. The tube can be tilted in a direction across the lead strips, but if it is, the angle must be small to prevent loss of density due to absorption of primary radiation. Figure 3-11 shows how two different tube angles, one approximately parallel with the lead strips and the other approximately at right angles to the strips, affect the transmission of photons through a grid.

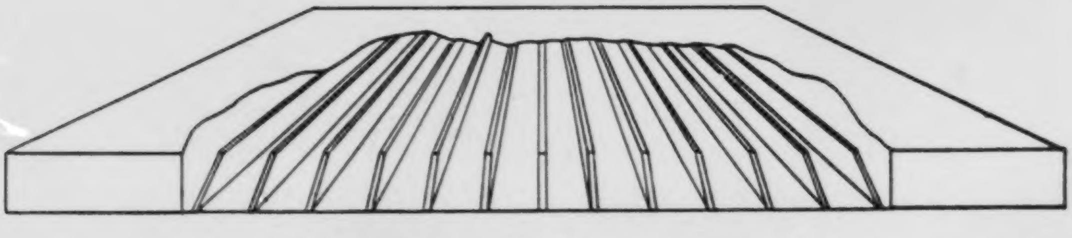


Figure 3-7. Cutaway of a focused grid.

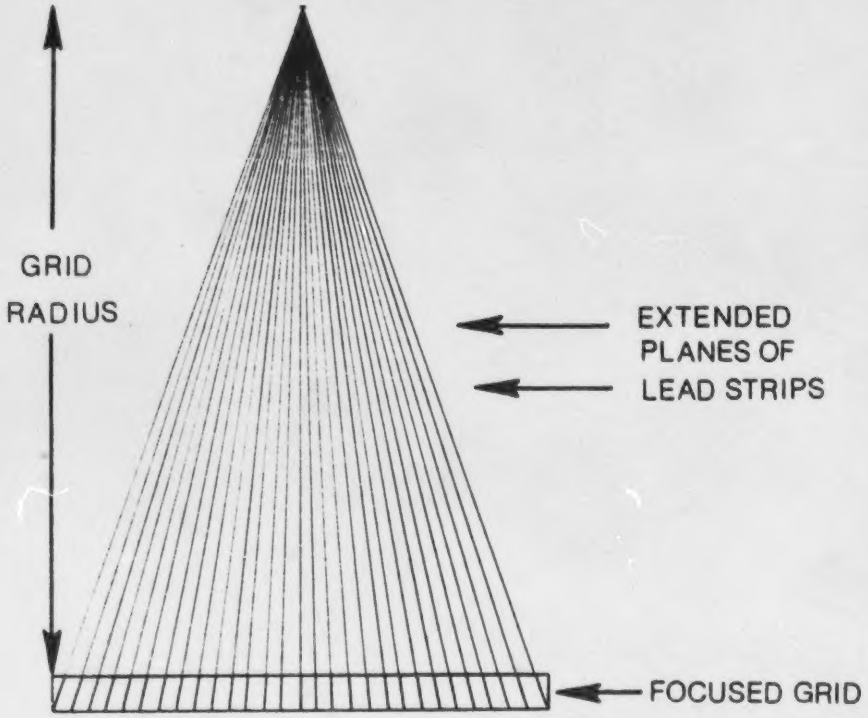


Figure 3-8. Grid radius.

Since a cross grid is actually made up of two superimposed linear grids, its effective ratio is about twice its nominal ratio. For example, an 8:1 crossed grid has an effective ratio of about 16:1.

Exercises (052):

Match the grid in column B with the appropriate statement or phrase in column A by placing the letter of the column B item in the appropriate space in column A. Each column B item may be used once or more than once. In addition, both column B items may match a single column A item.

Column A

___ 1. In X-ray tables.
___ 2. In grid-cassettes.
___ 3. Should be used with large tube angles.
___ 4. Has higher effective ratio.
___ 5. Use is more limited.
___ 6. Portable grid.

Column B

a. Linear.
b. Crossed.

053. Given a list of statements pertaining to the purpose, operation, and exposure requirements of Buckys, indicate which are true and which are false. If you indicate "false," explain your answer.

Grid Movement. As you know, if the patient moves during an exposure, the part being radiographed is blurred or not well visualized. If movement is considerable and the part is small enough, the part is completely obliterated. Such is the case when a grid is used in a Potter-Bucky diaphragm, a device named after its inventors, which moves the grid during exposure. Movement of the grid blurs out the lead strips that would otherwise appear on the film with a stationary grid. Grid lines, as you know, can interfere with interpretation of a radiograph.

Bucky operation. In order for a Potter-Bucky diaphragm (hereafter called a Bucky) to prevent grid lines on a radiograph, movement of the device or grid must satisfy the following three requirements: (1) motion must be smooth and even, (2) movement must start before the exposure, and (3) movement must continue until after the exposure stops.

Types of Buckys. Buckys can be classified as *moving*, as *reciprocating*, or as *recipromatic*.

A moving Bucky is one in which the grid only moves in one direction during a single exposure. It is then manually cocked before the next exposure. The speed of movement is determined by a timer, which also is manually set. When using this type of Bucky, be sure to cock the device before each

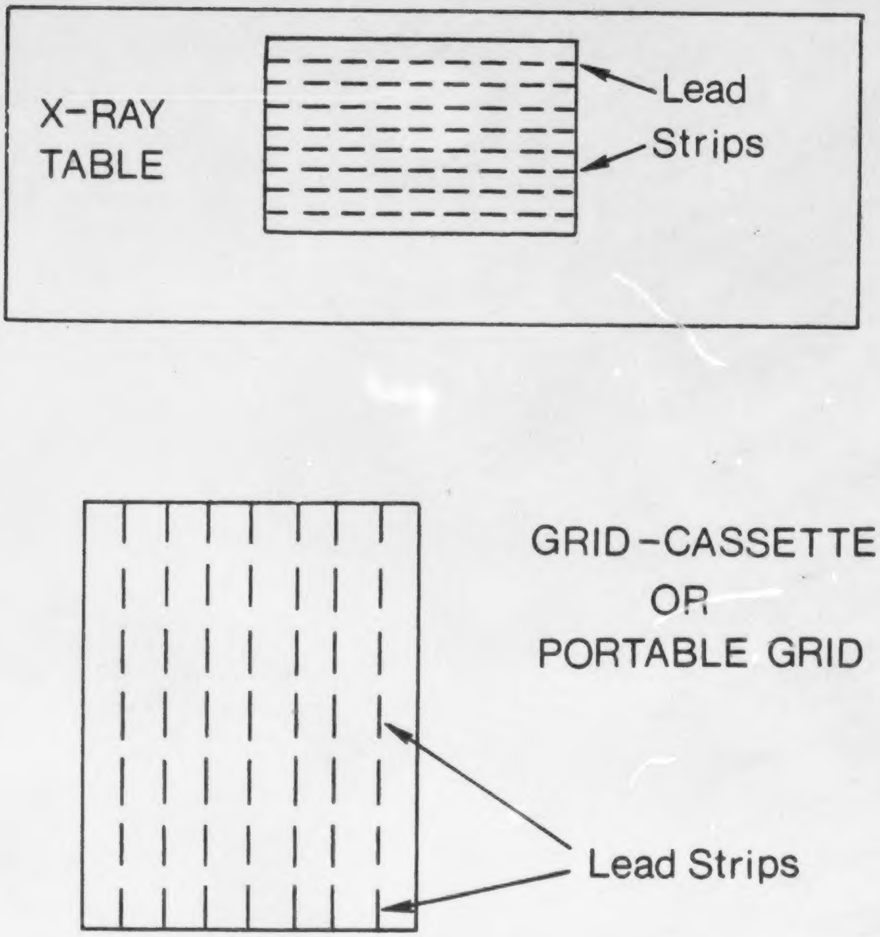


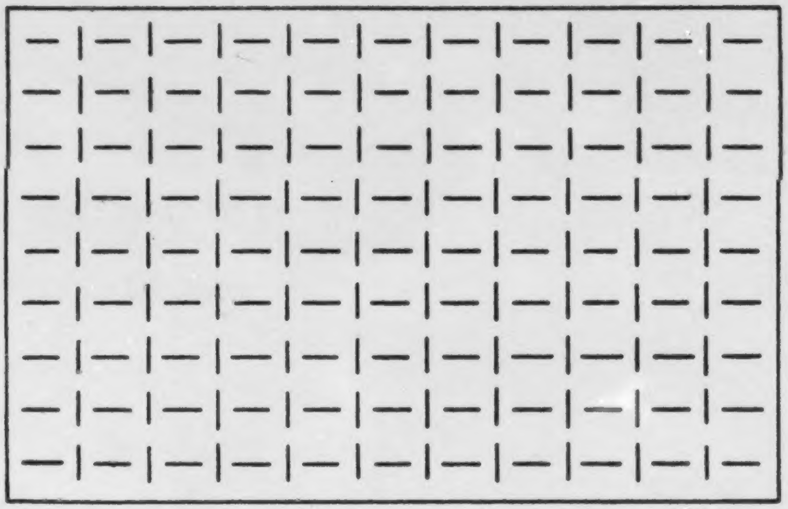
Figure 3-9. Direction of the lead strips in a linear grid.

exposure. Also, set the timer longer than the actual exposure to insure that grid movement occurs for the duration of the exposure. Some portable Buckys are of this type, but unless an X-ray machine is relatively old, it probably will not have this type of Bucky. Minimum exposure time without grid lines is about 1/10 second.

A reciprocating Bucky continually moves across the table and back for the duration of the exposure. Movement in one direction is slower than in the other. This type of Bucky does not have to be manually set. Minimum exposure time also is about 1/10 second.

A recipromatic Bucky moves at the same rate of speed in both directions across the X-ray table. It is made with different speeds, some fast enough to prevent grid lines, even at very short exposure times. Many of the newer X-ray machines have a recipromatic Bucky.

Exposure compensation. If you perform two radiographs with all factors equal except that one is made with a stationary grid and the other with a Bucky, the Bucky radiograph will be lighter. One reason for this is that more primary radiation is absorbed because the CR does not strike the (focused) grid in the exact center for the entire exposure. The effect is the same as having the tube centered laterally over the grid. Another reason is that the X-ray tabletop acts as an additional filter and therefore reduces the radiation reaching the film. Usually about 15 percent more exposure (mAs) is required.



Fgiure 3-10. Direction of the lead strips in a crossed grid.

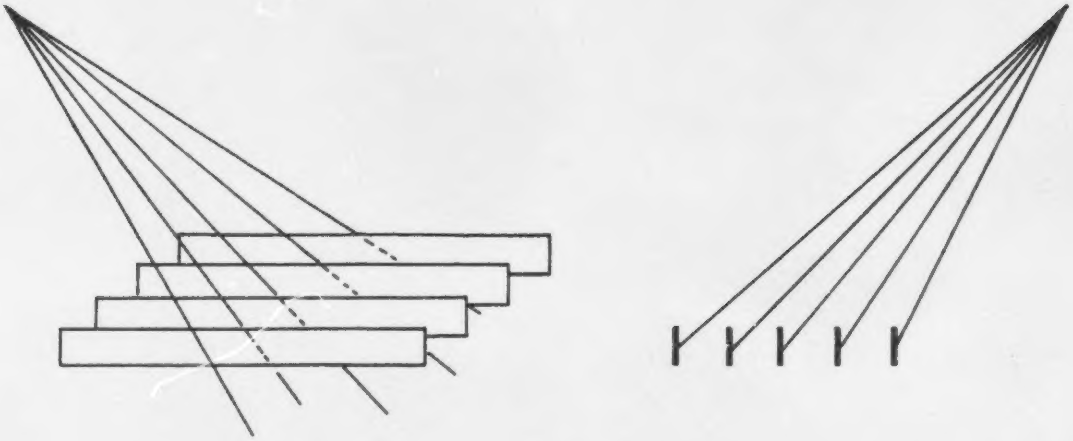


Figure 3-11. Relationship between direction of tube angle and direction of lead strips, showing the difference between the absorption of primary radiation.

Exercises (053):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. The purpose of a Bucky is to prevent unwanted shadows on a radiograph.
T F 2. Duration of movement is an important factor in the operation of a Bucky.
T F 3. A reciprocating Bucky permits the shortest exposure time.
T F 4. A reciprocating Bucky must be manually cocked before each exposure.
T F 5. The timer is manually set on a recipromatic Bucky.
T F 6. All Buckys must begin movement before the exposure to prevent grid lines.
T F 7. The X-ray table reduces film exposure.
T F 8. With Bucky exposures, the X-ray tube is not always aligned to the center of the grid.
T F 9. A 15-percent increase in exposure is necessary when changing from Bucky to stationary grid technique.

054. Given particulars pertaining to four pairs of grids, select the most efficient grid from each pair, and explain why the selected grid is more efficient.

Grid Efficiency. Grid efficiency refers to the amount of scatter radiation absorbed compared to the amount of primary radiation absorbed. Ideally, a grid would absorb all of the scatter and no primary photons. But due to the lead content in a grid, a portion of the primary beam is also absorbed. Consequently, grids are not 100 percent efficient.

Effect of grid ratio on grid efficiency. As a general rule, the higher the effective ratio of a grid, the better the absorption of scatter radiation. This increase in scatter absorption is shown in figure 3-12, which shows lead strips from two grids with different ratios. Notice that the angle of emission, by which scattered photons can reach the film between the lead strips, is larger with the low ratio grid. Consequently, the smaller ratio grid absorbs fewer photons. Also, notice that a scattered photon must penetrate more lead strips to reach the film through the high ratio grid; consequently, the photon has a better chance of being absorbed.

Effect of lines per inch on grid efficiency. Earlier in this section we briefly discussed how the number of lines per inch affects the contrast on a radiograph. We said that the higher the lines per inch for a given ratio, the lower the contrast because less scatter is absorbed due to the decrease in lead content. Therefore, lines per inch also affects grid efficiency. Another factor that affects the effeciency of a grid with many lines per inch (microline grid) is the kVp. If you use high kVp with a microline grid, the efficiency is reduced even more because some scattered photons produced by high kVp have higher energies than those produced by low kVp. Since the lead strips in a microline grid are thinner, they are more likely to be penetrated by the higher energy, scattered photons. This means that the grid absorbs fewer scattered photons and is therefore less efficient.

Exercises (054):

In the exercises below, select the more efficient grid of the two described, if all other factors are equal. Explain why the grid you select is more efficient.

1. Grid A - nominal ratio 5:1 - linear.
   Grid B - nominal ratio 5:1 - crossed.

2. Grid A - 8:1.
   Grid B - 12:1.

3. Grid A - microline - used at 70 kVp.
   Grid B - microline - used at 120 kVp.

4. Grid A - 100 line.
   Grid B - 133 line.

055. Indicate the effect and basic concepts of lateral decentering of the X-ray tube, and specify the maximum decentering allowable for specific grids.

Problems of Grid Exposure. Four major problems that technicians experience when using grids are: (1) lateral decentering—the X-ray tube is not aligned directly in the center of the transverse axis of the grid; (2) distance decentering—the tube is not positioned at the proper distance from the grid; (3) a combination of (1) and (2) above; and (4) off-angle alignment—the tube is improperly angled with respect to the direction of the lead strips. In all of these, there is a reduction in transmission of primary radiation due to increased absorption by the lead strips.

Lateral decentering. Lateral decentering is a problem frequently encountered when using a stationary grid because there is no mechanical means of centering the tube to the film. Lateral decentering causes an even loss of density over the entire film. Transmission of primary radiation begins to decrease with any amount of lateral decentering. The specific degree of reduction

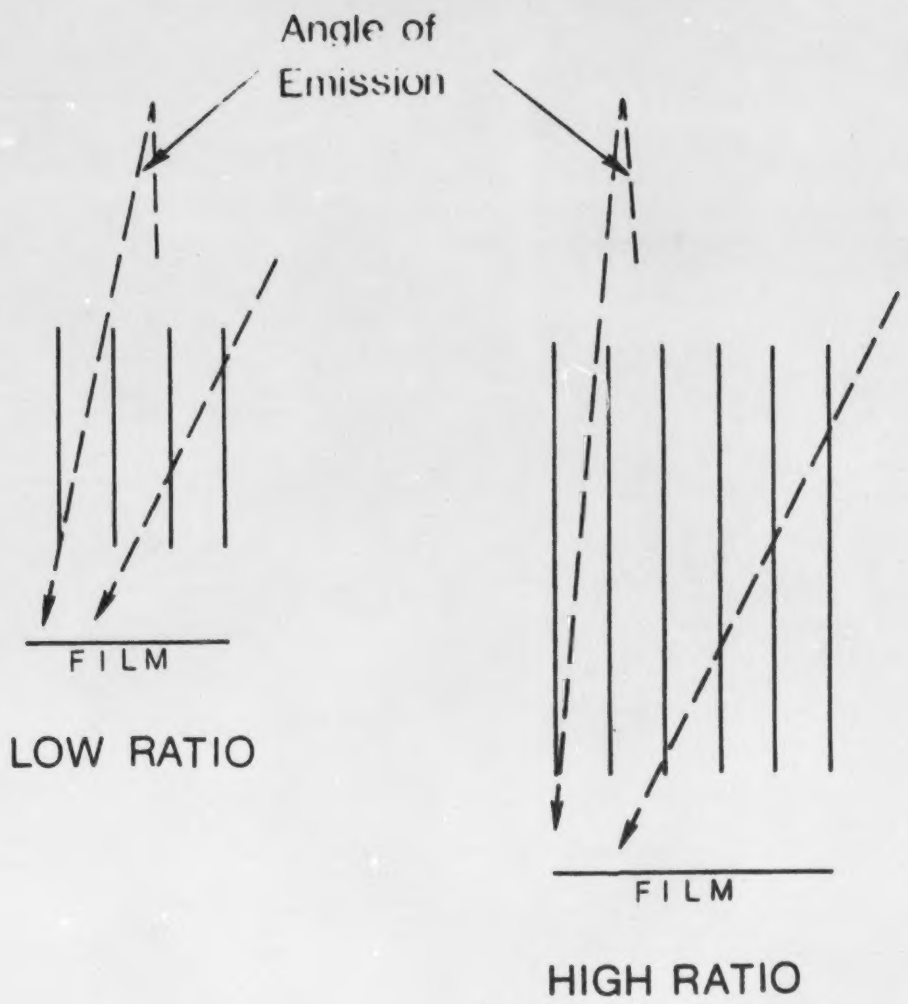


Figure 3-12. Effect of grid ratio on absorption of scattered X-ray photons.

depends upon the grid ratio, the grid radius, and the amount of decentering.

The higher the grid ratio, the more critical is the tube alignment. With all 16:1 grids, tube centering is so critical that 1 inch of lateral decentering is enough to reduce primary transmission to the point that the radiograph is too light for interpretation. Consequently, a 16:1 grid should only be used in places where lateral decentering is not a problem, such as in the X-ray table.

The shorter the grid radius, the more critical is the tube alignment. For example, a grid with a radius of 40 inches absorbs approximately twice as much primary radiation as does a grid with a radius of 72 inches. (This is based on two grids of equal ratios with equal amounts of decentering.)

As the amount of decentering increases, so does the absorption of primary radiation. Table 3-1 shows the maximum amount of decentering that still transmits about 80 percent of the primary radiation—enough to produce a diagnostic radiograph in most cases.

Exercises (055):

1. An X-ray tube is laterally decentered over a grid. How does this condition affect the appearance of the radiograph?

TABLE 3-1

MAXIMUM LATERAL DECENTERING WITHOUT SIGNIFICANT LOSS OF PRIMARY RADIATION

Grid Ratio	Grid Radius	Maximum Decentering (in inches)
5:1	40	2
	72	3
8:1	40	1
	72	2
12:1	40	0
	72	1
16:1	40	0
	72	0

2. Two radiographs are made, using 8:1 and 5:1 grids, with 1 inch of lateral decentering in each radiograph. Which radiograph shows less loss of radiographic density if all the other factors are equal?

3. How does the grid radius affect radiographic density in the presence of lateral decentering?

4. How much lateral decentering is permitted using a 8:1, 40-inch, focused grid?

5. How much lateral decentering is permitted using a 16:1, 72-inch, focused grid?

6. Which of these two grids permits the most lateral decentering without significant loss of density—8:1, 40-inch, focused, or 5:1, 72-inch, focused?

056. Relate focus-grid distance to grid radius and radiographic density.

Distance decentering. Distance decentering refers to the use of a focus-grid distance which is more or less than the grid radius. The result on the radiograph is a reduction in the primary radiation toward the lateral edges of the beam with little or no effect on the central portion of the primary beam. The specific loss of primary radiation depends upon the amount of decentering, the grid ratio, and the direction (near or far) of the decentered tube.

The loss of primary radiation increases as the distance between the grid radius and the X-ray tube increases. There is a certain amount of tolerance for this type of decentering. The tolerance depends partly upon the grid ratio. A grid with a high ratio will not tolerate as much distance decentering as will a grid with a low ratio. Also, there is more tolerance if the distance from the X-ray tube to the grid is greater than the grid radius and less tolerance if the distance from the X-ray tube to the grid is less than the grid radius.

When we speak of "tolerance," we mean the maximum amount of decentering which still produces sufficient density to produce a diagnostic radiograph. Some grids have a specified focal range, such as 30 inches to 40 inches. This means you can use any focus-grid distance in that range without experiencing significant loss of primary radiation.

Some grids do not come with a specified focal range. Only the grid radius is specified. In cases such as this, you should get in touch with the manufacturer and obtain his recommendations, although you can determine the relative tolerance of various grids by making experimental exposures and determining at what focus-grid distances significant loss of primary radiation (density) occurs.

Exercises (056):

1. If a radiograph is made using a 35-inch focus-grid distance and a grid with a focal range of 36 to 44 inches, how does this condition affect the appearance of the radiograph?

2. Two radiographs are made using a 40-inch focused grid. A 48-inch focus-grid distance is used with one radiograph and a 32-inch focus-grid distance is used with the other. Which radiograph shows the greater change in appearance if all other factors are equal? Explain.

3. How does grid ratio affect the loss of primary radiation due to distance decentering?

4. How can you determine the focal range of a grid if it is not specified?

057. Given descriptions of the density distribution of two radiographs, specify the cause of the difference in distribution.

Lateral decentering plus distance decentering. When lateral and distance decentering occur together during the same radiograph, they are unique in that they produce a radiograph with a loss of density on only one lateral margin of the film. If the X-ray tube is misaligned in both directions and the focus-grid distance is greater than the grid radius, the lateral margin of the film beneath the tube is underexposed. If the focus-grid distance is less than the grid radius, the lateral margin of the film remote from the tube is underexposed. See figure 3-13.

Exercises (057):

1. A radiograph shows uneven density. The density on side A of the radiograph is greater than the density on side B. Based on the information in the text, what is the probable cause(s) of the variation?

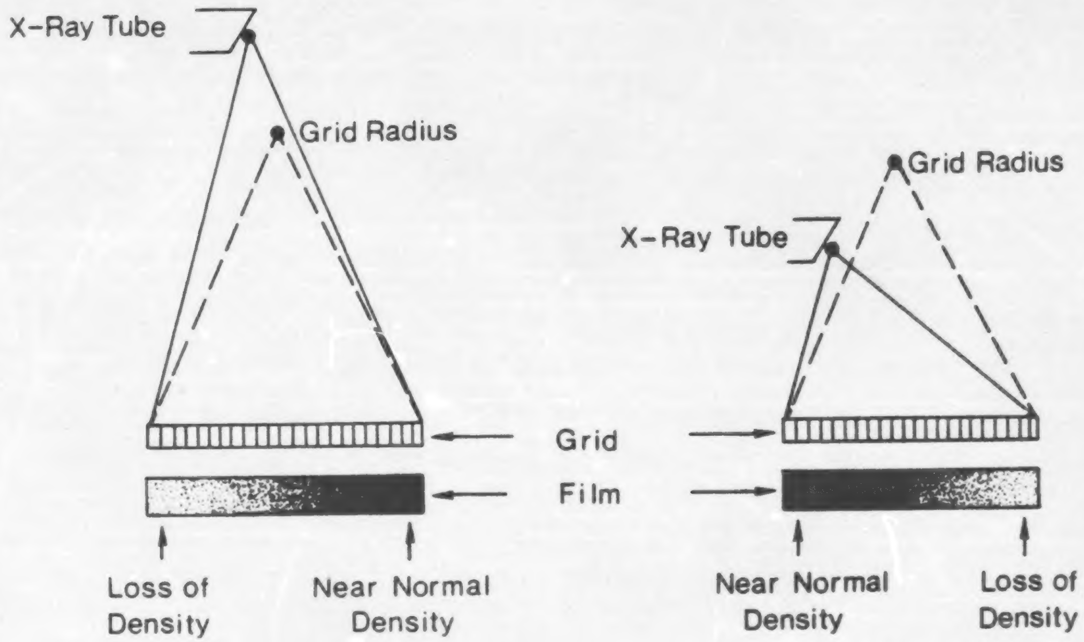


Figure 3-13. Effect of lateral decentering plus distance decentering on film density.

2. A radiograph shows uneven density. The density on side A of the radiograph is less than the density on side B. Based on the information in the text, what is the probable cause(s) of the variation?

058. Specify the maximum tube angle allowed across the grid strips for various grids; describe the appearance of the radiograph if the maximum angles are exceeded.

Off-angle alignment. If the X-ray tube is excessively angled across the lead strips, there is an even, noticeable loss of density over the entire film. The amount of loss depends upon the degree of the angle and grid ratio. The maximum (approximate) angles which still produce adequate film exposure for specific grids are as follows: 5:1, 8°; 8:1, 6°; 12:1, 3°; and 16:1, 1°.

Exercises (058):

1. What maximum tube angles are permitted across the grid strips for the following grids?

   a. 5:1.

   b. 8:1.

   c. 12:1.

   d. 16:1.

2. If the angles indicated in exercise #1 above are exceeded, what is the result on the radiographs?

Film, Film Holders, and Darkroom

AS YOU ACHIEVE your "7 level" and advance in grade you will become more and more involved in the selection of films and film holders for use in your department. In this chapter we will present some general information about these two items to assist you in your selections, as well as other information to help you use them effectively.

Our discussion of darkrooms will cover the chemistry, the evaluation, and the standardization of processing systems.

4-1. X-Ray Film

In this section we will discuss the composition of an X-ray film, the types of film, and film characteristics.

059. Given a list of statements pertaining to the composition of an X-ray film, match each with the appropriate film layer.

Composition of an X-ray Film. An X-ray film consists of a base, two subcoatings, an emulsion on both sides, and a protective coating. (See fig. 4-1.)

The base. The base consists of either cellulose acetate or polyester and serves as a support for the emulsion and subcoating. It also provides the proper degree of stiffness for easy handling. Films with a cellulose acetate base work quite well in manual processing and in some of the slower automatic processors. However, in 90-second, automatic processors where high temperatures are used, they have a tendency to slip and cause the machines to jam. This occurrence is attributed to the absorption of fluids by the cellulose acetate base. Polyester, as base material, provides more strength in thinner form than does cellulose acetate and will not absorb fluids. Consequently, polyester-base film is more compatible with the high temperatures used in 90-second processors.

The subcoating. The subcoating is a thin layer of adhesive material used to attach the emulsion to the film base.

The emulsion. Basically, the emulsion is composed of gelatin and silver bromide crystals. The latent image and visible image are formed in the film emulsion.

The protective coating. A thin, transparent material is coated over the emulsion to protect it during handling and storage.

Exercises (059):

Match the X-ray film layer in column B with the appropriate statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or not at all.

Column A	*Column B*
___ 1. Located between the emulsion and base.	a. Base (cellulose acetate).
___ 2. Should not be used in 90-second processors.	b. Base (polyester).
	c. Subcoating.
___ 3. Helps prevent damage to the emulsion.	d. Emulsion.
	e. Gelatin.
___ 4. Can withstand high temperature processing.	f. Protective coating.
___ 5. Gelatin and silver bromide.	

060. Given a list of statements pertaining to the three types of X-ray films, match each with the appropriate film.

Types of X-ray Film. Many different types of film are used in the radiology field. All of these can be combined into the two major groups known as screen and nonscreen films. These two groupings include every film type except dental, which has a few peculiarities of its own. Dental films are also discussed since you will, at times, use them.

Screen film. Screen film is manufactured to be especially sensitive to the blue-violet light emitted from intensifying screens. The purpose in using these screens is to amplify the effects of X-radiation, as will be explained in more detail throughout this chapter. Screen film contains a smaller amount of silver than does nonscreen film; this factor permits screen film to be processed faster than nonscreen film. Most radiographic examinations are accomplished using screen film with intensifying screens; however, screen film can be used without intensifying screens. When used without screens, these films require considerably more exposure.

Nonscreen film. Nonscreen film is designed to be especially sensitive to the direct action of X-rays. When used in this manner, it provides excellent radiographic detail. Generally speaking, it is intended for use only on smaller body parts, such as

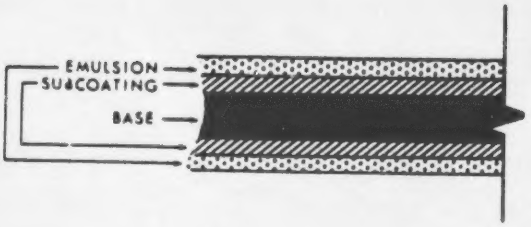


Figure 4-1. Cross section of an X-ray film.

the extremities and breasts. In actual practice, nonscreen films are usually used in mammography, and screen films are used on extremities. Since a nonscreen film has a larger amount of silver, it will have a higher degree of contrast in the lower exposure ranges. Since the emulsion is thicker in nonscreen films, they require a longer developing and fixing time. Also, because of the thick emulsion, nonscreen films should not be used with intensifying screens because the visible light emitted by the screens cannot penetrate and completely expose the entire emulsion layer.

Dental film. This brings us to dental film, which—as was mentioned earlier—has some peculiarities. Dental films are simply modifications of medical X-ray film. They are individually wrapped in moistureproof, lightproof packets and are classified as periapical (used for examining the roots of the teeth), interproximal (for locating cavities between teeth), and occlusal (for examining larger areas). Specifically, dental film has a thinner base and emulsion than does medical X-ray film, and is supplied two to a package, with a lead-foil backing. The amount of exposure required is similar to that of nonscreen film.

Exercises (060):

Match the type of film in column B with the information in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once, or more than once.

Column A	*Column B*
___ 1. Used in mammography.	a. Screen film.
___ 2. Particularly sensitive to blue-violet light.	b. Nonscreen film.
___ 3. Used more than other types.	c. Dental film.
___ 4. Two to a package.	
___ 5. Provides greater detail for smaller parts.	
___ 6. Can be used with or without intensifying screens.	
___ 7. Used for lateral lumbar spine.	
___ 8. Requires longer processing.	
___ 9. Has thicker emulsion.	

061. Define density, and given three percentages of light transmitted through a radiograph, specify the numerical density values.

Film Characteristics. All X-ray films are not the same—that is, they differ in such properties as speed and contrast. The best way to compare these properties is to refer to the characteristic curve, which can be obtained from the manufacturer. We will discuss some characteristic curves, but first let's review film density.

Density. Density, as you know, is the ratio of the light transmitted through an X-ray film to the light incident to the film. The less the light transmission, the higher the density.

When we look at an X-ray film, we usually think of density in relative terms. We may think of doubling the density or halving the density with little thought of what the specific density measurement is. By using an instrument called a densitometer, we can measure the actual density on a radiograph.

Density is expressed in logarithmic values. While you do not need to understand logarithms, you should be familiar with the specific density values. If a densitometer shows that the density of a particular portion of a radiograph is 1.0, 10 percent of the incident light is transmitted through the film. A density of 2.0 means that 1 percent of the light is transmitted, and a density of 3.0 shows that 0.1 percent of the incident light is transmitted through the film.

Exercises (061):

1. What is density?

2. What specific density is present if each of the following percentages of incident light is transmitted through a radiograph?
   a. 10 percent.
   b. 1 percent.
   c. 0.1 percent.

062. Given a characteristic curve of an X-ray film, determine what mAs changes are required to produce specific changes in the density on a radiograph.

Now, let's examine a typical characteristic curve and see what we can learn about a particular X-ray film. Figure 4-2 shows a characteristic curve. As you can see, the density is plotted on the vertical axis, and the log relative exposure, on the horizontal axis. Log relative exposure represents the mAs required to produce a specific change in the density. An increase of 0.3 on the exposure scale represents double the mAs and a decrease of 0.3 represents half the mAs. For example, if 10 mAs produces a density of 1.1, 20 mAs will produce a density of 1.8 (notice the broken lines). Keep in mind that the log relative exposure scale is *relative*. You can apply any mAs value to the scale. One hundred mAs produces a density of 1.1; then 200 mAs is required to produce a density of 1.8, according to the curve in figure 4-2.

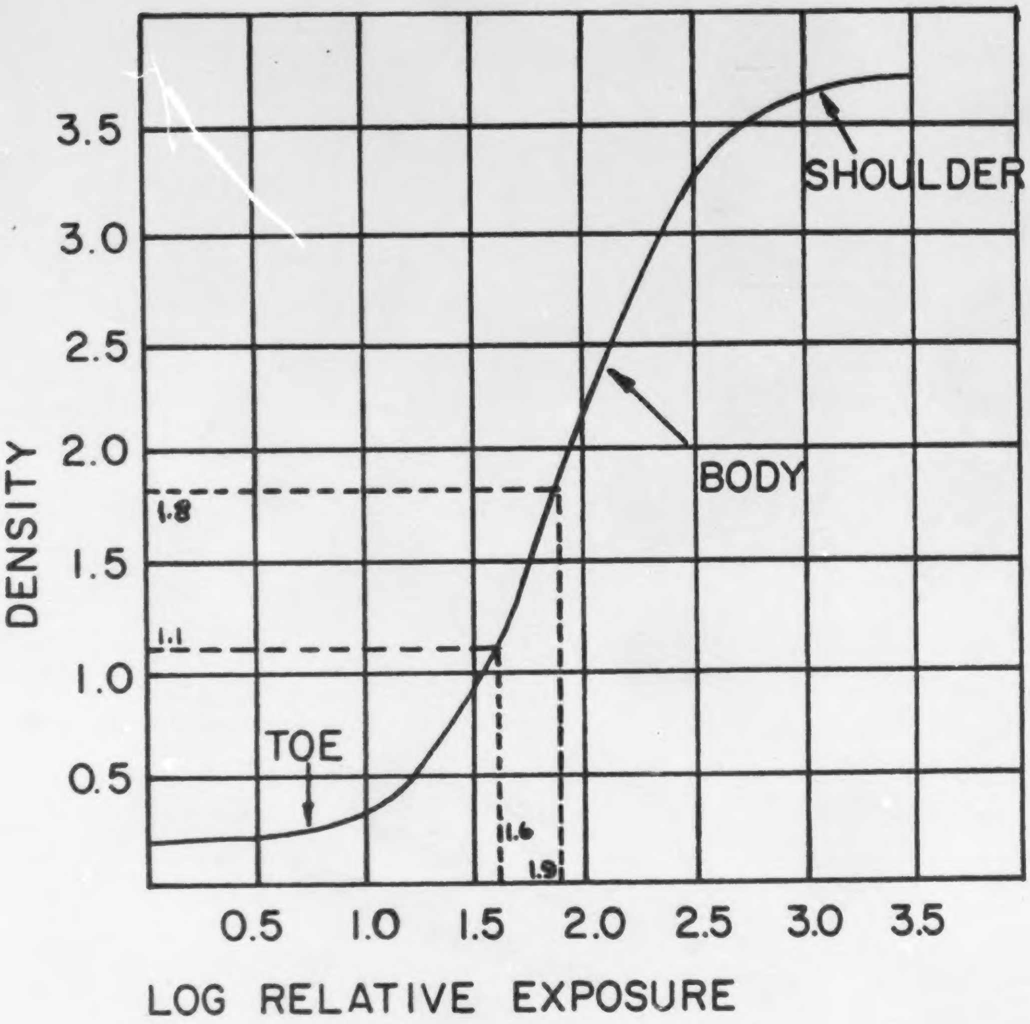


Figure 4-2. A characteristic curve.

Exercises (062):

Using the characteristic curve in figure 4-3, complete the following exercises.

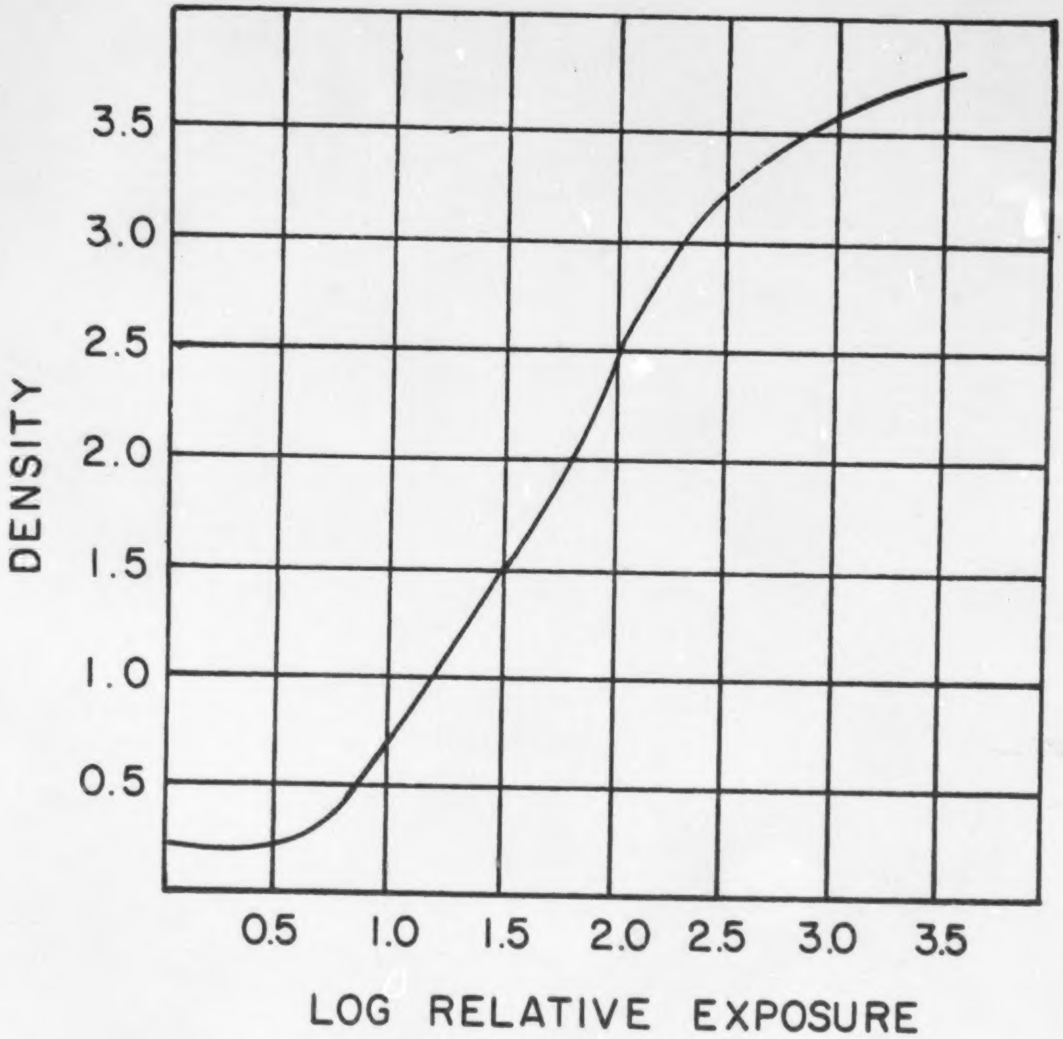


Figure 4-3. Objective 062, exercises 1 and 2.

1. If 30 mAs produces a film density of 1.5, how much mAs is required to produce a density of 2.0?

2. If 35 mAs produces a film density of 1.6, how much mAs is required to produce a density of 0.7?

063. Given characteristic curves of three different X-ray films, evaluate them in terms of background density, film speed, contrast, and exposure latitude.

Background density. All X-ray films have a certain amount of background density, also called inherent film fog. This density is present after processing even if the film is unexposed. To determine the background density of a film, refer to the toe of the characteristic curve and note the density at zero exposure. The film represented in figure 4-2 shows a background density of 0.2. As a rule, a background density of over 0.2 is excessive.

Film speed. The response of a radiographic film to exposure is called film sensitivity or film speed. A "fast" film requires less exposure to produce a specific density than does a "slow" film. Since a fast film requires less exposure, it permits shorter exposure times, subjects the X-ray tube to fewer heat units per exposure, and reduces the radiation dose to the patient. Fast films, however, usually sacrifice some detail due to the increased size of the silver bromide crystals in the emulsion, which causes a "grainy" appearance on the radiographs.

Film speeds are not expressed in numerical values; therefore, you must compare the relative speeds of different films by referring to the characteristic curves. The relative speed of a film is indicated by the left to right position of the characteristic curve on the graph. The farther to the left the curve is located, the faster the speed. The farther to the right—the slower the speed.

Contrast and exposure latitude. You can also determine the relative film contrast and exposure latitude by evaluating the characteristic curves. Both are indicated by the slope of the curve. A more vertical slope indicates higher contrast and less exposure latitude, and a more gradual slope indicates lower contrast and more exposure latitude.

Exercises (063):

Complete the following exercises based on the three characteristic curves shown in figure 4-4.

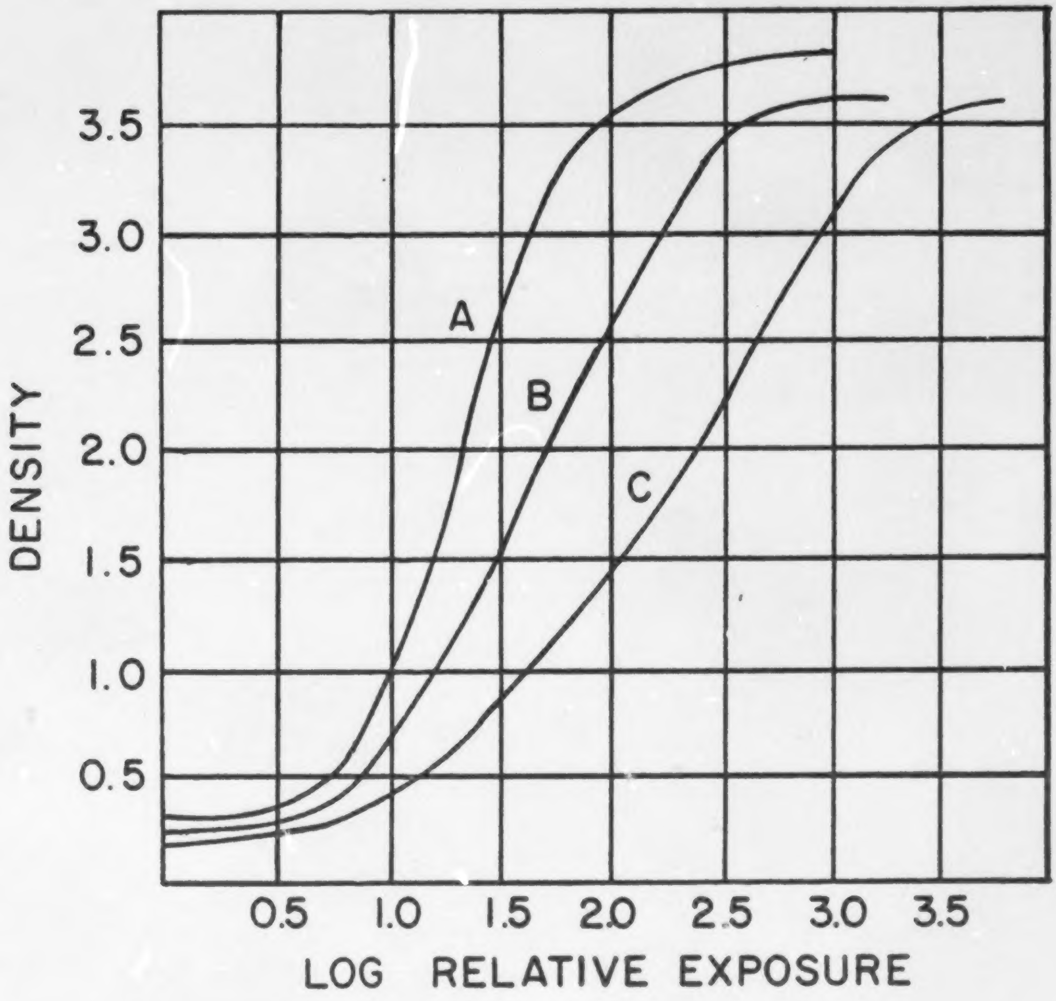


Figure 4-4. Objective 063, exercises 1 through 8.

1. Which film has the highest background density?
2. Which film(s), if any, has too much background density?
3. Which film is the slowest?
4. Which film would expose your patients to the least radiation?
5. Which film would cause the most strain on your X-ray tube?
6. Which film exhibits the highest contrast?
7. Which film provides the most exposure latitude?
8. Which film sacrifices the most detail?

4-2. Intensifying Screens

Our discussion of intensifying screens includes their purpose, construction, significance of the phosphor, and finally the procedures for performing screen-film contact and screen lag tests.

064. State the purpose of intensifying screens; list the four layers of an intensifying screen, and give the purpose of each.

Purpose of Intensifying Screens. As you know, intensifying screens reduce the exposure necessary to produce the desired density on a radiograph. They reduce the exposure by converting the radiant energy (X-ray photons) to visible light, which then exposes the X-ray film.

Construction of Screens. An intensifying screen consists of four layers of material—the base, the reflecting material, the phosphor, and the protective coating.

Base. The base is a sheet of cardboard or similar material that supports the rest of the screen.

Reflecting material. The reflecting material is a thin layer of substance that reflects the light photons emitted away from the film, back toward the film.

Phosphor. The phosphor is the chemical that emits visible light when exposed to X-rays.

Protective coating. The protective coating is a thin layer of plastic that prevents the buildup of static, protects the phosphor, and permits the screen to be cleaned without damage to the phosphor.

Exercises (064):

1. What is the purpose of intensifying screens?

2. List the four layers of an intensifying screen and give the purpose of each layer.

065. Indicate the relationship between the intensifying screen phosphor and screen characteristics.

Phosphor Significance. The layer of phosphor in an intensifying screen is usually made up of crystals of calcium tungstate. When X-ray photons strike these crystals, the crystals emit visible light in the blue-violet range of the spectrum. X-ray films designed for use with intensifying screens are particularly sensitive to the blue-violet light.

Screen speed. Depending upon the size of the screen crystals and the thickness of the layer of the crystals, intensifying screens are classified according to their speeds. The speed reflects the sensitivity of the phosphor layer to X-radiation. "Slow," "medium," and "fast," are common screen speeds, although different manufacturers apply other terms to their screens. The faster the screens, obviously the less exposure needed to produce a given density on a radiograph. As a rule, large crystals and a thick layer provide a fast screen, while small crystals and a thin layer reduce the speed of the screen.

Detail. On the surface it would seem that high speed screens are best since they permit shorter exposure times, less strain on the X-ray tube per exposure, and less radiation to the patient. However, these advantages are realized only by sacrificing detail on the radiographs. All intensifying screens reduce the detail on a radiograph below that obtained from direct film exposure, and this reduction in detail is increased as the speed of the screens increases.

Notice in figure 4-5 that we have shown illustrations of two layers of crystals of different thicknesses. Notice that the visible light from some of the phosphor crystals from the thick layer is more diffused because the crystals are farther from the film. The greater diffusion results in more overlapping of the areas under exposure and, consequently, less image clarity.

Figure 4-6 also compares the diffusion of the light, but between large and small crystals. There is more overlapping of the light from the large crystals because they emit more light than the small crystals.

Exercises (065):

1. Describe the connection between screen spectral emission and film sensitivity.

2. Of the three screen speeds listed in the text, which one requires the least exposure for a specific examination? The highest exposure?

3. Of the three screens listed in the text, which one provides the best detail? The least?

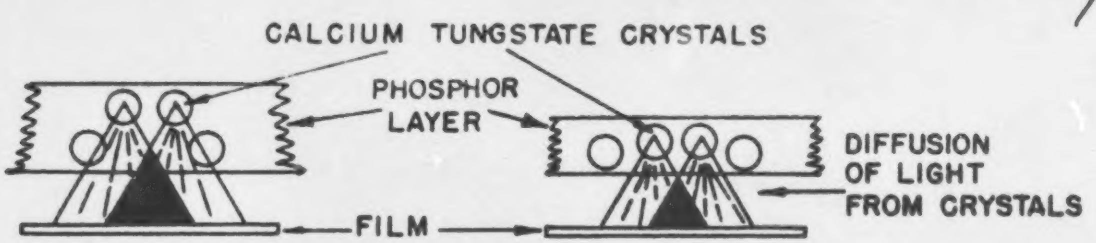


Figure 4-5. Caomparison of light diffusion between thick and thin layers of screen phosphor.

4. In your own words, explain the relationship between crystal size, layer thickness, and detail.

5. Why do crystal size and layer thickness affect detail?

066. Given a list of statements pertaining to a screen-film contact test, indicate which are true and which are false. If you indicate "false," explain your answer.

Screen-Film Contact. Screens must be in close, even contact with the film; otherwise, the film will have a fuzzy appearance, and there will be a definite loss of detail. The detail loss is due to the increased light diffusion from the crystals because they are farther from the film. See figure 4-7. Poor screen-film contact is generally caused by screen warpage resulting from moisture, loose fitting due to broken hinges, improper spring tension in the latches, uneven surface caused by a foreign object under the screen, or defective cassette frames. You can test the screen-film contact quickly and easily in this way: place a piece of wire mesh on the outside of a loaded cassette and make a flash exposure at about 5 mAs and 40 kVp. After developing, inspect the image of the wire mesh. If the contact is good, the image will be sharp and clearly defined throughout the surface of the film. If it is poor, the outline will be fuzzy, with varying degrees of unsharpness. Figure 4-8 shows two wire mesh images. The one on the left exhibits good contact; the one on the right, poor contact. Although the poor contact in the figure is throughout the film, this may not necessarily be the case. Poor screen contact can occur in only a small area in the cassette, such as the center. Regardless of the size of the area involved, if it causes a significant loss of detail, the cassette must be repaired or replaced.

Exercises (066):

T F 1. A screen-film contact test is made to determine if there is an increase in detail.

T F 2. Poor screen-film contact results in less light diffusion from the phosphor crystals.

T F 3. To perform a screen-film contact test, make a radiograph of a piece of wire mesh.

T F 4. Unsharp areas on a test radiograph indicate good screen-film contact.

067. Given descriptions of the results of three screen lag tests, evaluate the results and determine if screen lag is present.

Screen Lag. One requirement of good screens is

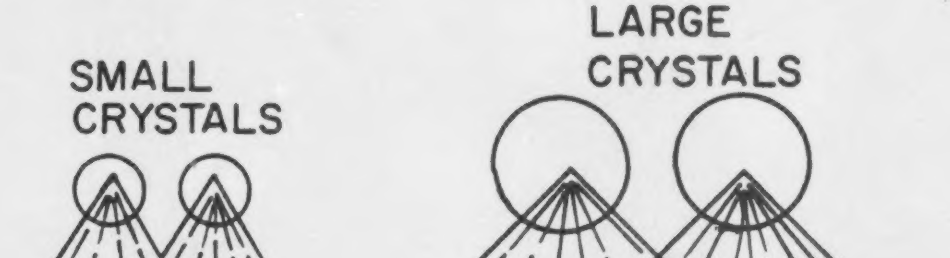


Figure 4-6. Comparison of light diffusion between large and small phosphor crystals.

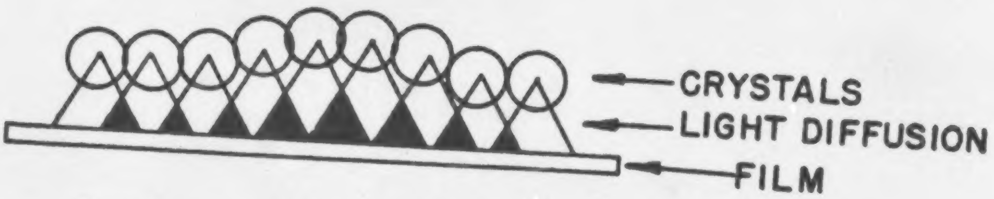


Figure 4-7. Poor screen contact showing increased light diffusion over the area of poor contact.

that fluorescence stops at the same time as does the exposure. When screens continue to fluoresce after the exposure has stopped, they are said to have lag or phosphorescence, and the image from one exposure is likely to be carried over to the next film loaded into the cassette. Test for screen lag in these ways:

a. Make an exposure and take the cassette into the darkroom immediately. Remove the exposed film and reload the cassette. Take the second film from the cassette a few minutes later and develop it. If a density appears, there is screen lag, and the screens should be replaced.

b. Expose an unloaded cassette and take it into the darkroom immediately. Take a film from the bin, cover half of it with black paper, and load it into the cassette. Leave the film in the cassette for a few minutes; then develop it. The half of the film covered with paper will show no exposure. If the half that was not covered by the paper shows an exposure, there is screen lag, and the screens should be replaced.

Exercises (067):

In the exercises below, evaluate the descriptions of the radiographs and indicate whether or not screen lag is present.

1. The film is not exposed.
2. An even exposure covers the entire film.
3. Half the film is exposed; the other half is not.

4-3. Film Processing

We assume you know by now the procedures for processing radiographs; therefore, we will not spend a great deal of time on the procedures. Most of this section will be devoted to evaluation and standardization of film processing. We will show you how to spot some processing problems even before the problems affect the appearance of the radiograph. In addition, we will discuss ways to standardize all the processors in your department so that you can process a particular radiograph in any processor and obtain the same results. Our discussion begins with a review of the chemistry of film processing.

068. Given a list of the chemicals used in processing radiographs, match each with selected statements pertaining to their functions.

Processing Chemistry. Although several chemicals perform various functions in the developer and fixer, we can say that the general functions of the two are as follows: developer reduces the exposed silver bromide crystals to black

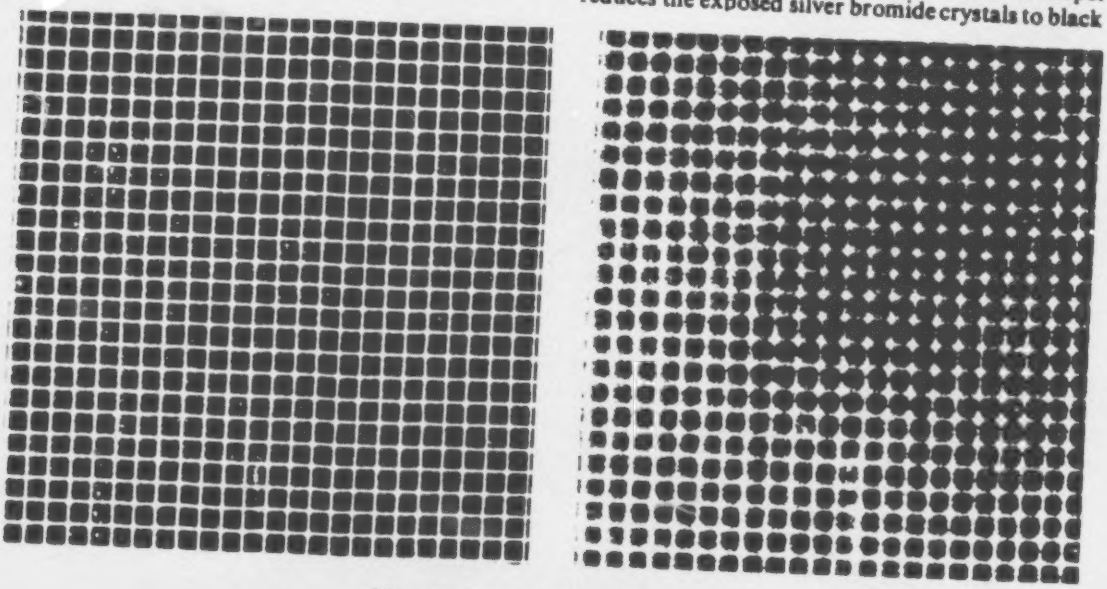


Figure 4-8. Screen-film contact test.

metallic silver; fixer removes the unexposed silver bromide crystals from the film.

Manual developer. Basically, manual developer consists of four agents: (1) activator, (2) reducers, (3) restrainer, and (4) preservative:

a. Sodium carbonate, also called the activator or accelerator, provides the alkaline base needed to activate the other chemicals. It also causes the film emulsion to swell and soften, permitting access to the exposed silver bromide by other chemicals.

b. Metol and hydroquinone are known as the reducing agents. Together they reduce the exposed silver bromide crystals to black metallic silver. Metol acts quickly on the crystals and builds the gray tones of the image. Its action is unpredictable above 75° F. Hydroquinone is slower acting than metol. It builds up the black tones of the image, and therefore brings out the film contrast. Hydroquinone does not function effectively below 60 ° F. Manual developer should be maintained at 68° F. because of the sensitivity of these two chemicals.

c. Potassium bromide is the restrainer in the developer. It limits the action of the reducing agents to prevent development of the unexposed silver bromide crystals. If a film is left in the developer too long, the reducers will override the restrainer and develop the unexposed crystals, resulting in chemical fog. An important point to remember is that bromine, which is a byproduct of the development process, also acts as a reducing agent. It continues to build up throughout the life of the developer; consequently, there is no need to add potassium bromide to the replenisher.

d. Sodium sulfite is the "preservative" in the developer. Its purpose is to prevent rapid oxidation of the chemistry and thereby prolong the life of the developer.

Automatic developer. Basically, the automatic developer chemistry is the same as manual developer. Two chemicals, sodium carbonate and sodium sulfite, serve the same functions. Potassium bromide also serves the same function, but is called the starter solution. The starter is obtained separately from the automatic developer; whereas, the potassium bromide is included as part of the manual developer package. As with manual developer, potassium bromide is not included in automatic developer replenisher. Two other differences between the developers are as follows:

a. Metol cannot be used in automatic processors since the developer temperature is higher than 75° F., usually 80° to 100° F. Phenidone in automatic developer performs the same function as metol in manual developer. Hydroquinone is present in automatic developer and serves the same function as in manual developer.

b. Automatic developer contains a "hardener"—gluteraldehyde. The purpose of this chemical is to control the swelling of the emulsion and thereby to help prevent transport problems and damage to the emulsion by the transport rollers.

Fixer. The fixer in both manual and automatic chemistry contains four basic agents: (1) acidifier, (2) clearing agent, (3) hardener, and (4) preservative. The preservative is the same chamical, sodium sulfite, and serves the same function as in the developer.

a. Acetic acid, the acidifier, serves two functions: (1) it stops development by neutralizing the alkaline developer solution and (2) it provides the acidity required for the other chemicals to function.

b. The clearing agent in the fixer is either ammonium thiosulfate or sodium thiosulfate. It removes the unexposed silver bromide crystals from the film emulsion by dissolving them into solution as silver salts. Once the film is cleared, it can be safely exposed to light.

c. The hardener in the fixer is either aluminum chloride, potassium alum, or chrome alum. It shrinks and hardens the emulsion so that it can be handled without damage.

Exercises (068):

Match the processing chemical in column B with the appropriate statement in column A by placing the letter of the column B chemical in the space provided in column A. Each column B item may be used once, more than once, or not at all. In addition, more than one column B item may match a single column A statement.

Column A

— 1. Turns the exposed silver bromide crystals to black metallic silver.
— 2. Prevents chemical fog by limiting the action of the reducing agents.
— 3. Hardening agent in the developer.
— 4. Starter solution.
— 5. Removes unexposed crystals from film emulsion.
— 6. Manual developing temperature is based on these.
— 7. Permits reducing agents' entry to the exposed silver bromide crystals.
— 8. Hardens the film emulsion in the fixer.
— 9. Prevents oxidation of the chemistry.
— 10. Developer agent not added to replenisher.
— 11. Doesn't work properly below 60° F.
— 12. Reducing agent(s) which are dependable when temperature is above 75° F.

Column B

a. Potassium alum.
b. Metol.
c. Sodium thiosulfate.
d. Gluteraldehyde.
e. Sodium carbonate.
f. Hydroquinone.
g. Potassium bromide.
h. Sodium sulfite.
i. Phenidone.
j. Acetic acid.
k. Ammonium thiosulfate.
l. Aluminum chloride.

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069. State a common cause of inconsistent quality in radiographs, and briefly explain the procedure for evaluating processors.

Evaluation of Film Processing. As you know, the production of high-quality radiographs is important in a radiology department. Equally important is the *consistent* production of radiographs of high-quality. Several factors affect the consistency of the radiographs, and some of them are explained elsewhere in this volume. One of the most common causes of inconsistent quality of radiographs is that film processing varies from day to day and from one processor to another.

To identify the variations before they affect the radiographs or to prevent the variations altogether, you should check each processor daily, using a sensitometric film strip. Basically, the procedure is as follows: the film strip is exposed to light so that a series of densities are recorded on the film. After processing, the densities of certain density steps are determined with a densitometer and recorded on a chart.

Exercises (069):

1. What is a common cause of inconsistent quality radiographs?

2. Briefly explain the procedure for evaluating processors.

070. Answer key questions pertaining to the sensitometer and radiographic film when conducting a processor evaluation test.

Sensitometer. The first requirement for evaluating processors is to expose the filmstrips with a device capable of producing repeated equal exposures from one day to the next. Such a device is called a sensitometer. Using a sensitometer, you can be assured that the filmstrips receive equal exposures; consequently, a variation in film density can be accurately traced to the processor. You shouldn't expose the filmstrips with a radiographic unit because there are usually minor, day-to-day variations in machine output.

Commercial sensitometers are available, but one can be made at a relatively small cost. One "homemade" sensitometer is described in an article written by Trout, Kelly, and Anderson in *Radiologic Technology*, Volume 43, No. 1, 1971, pp. 15–19.

The procedure for exposing the radiographic film in the sensitometer is relatively simple and depends upon the device employed. Keep in mind that you should eliminate as many variable factors as possible in order to accurately evaluate your processing systems. It follows that you should reserve one box of radiographic film for the evaluation to prevent minor variations from one box of film to another from affecting the film densities. Also, expose a fresh film daily and immediately process it, since prolonged periods between exposure and processing may also affect the resulting film densities. If you have more than one processor, cut the film into strips after exposure and process a filmstrip in each processor. Be sure to identify the processor on the film strip.

Exercises (070):

1. When exposing radiographic films to evaluate processors, why is it better to use a sensitometer rather than a radiographic unit?

2. Why is it important to take your films from the same box?

3. How long after exposure should you process the filmstrips? Why?

071. Given a chart showing densities obtained from filmstrips processed in three different processors, evaluate the chart and answer key questions pertaining to the test data and results.

Evaluating filmstrips. Evaluation of the filmstrips is, of course, the most important aspect of the operation. We will discuss this aspect from two standpoints: (1) using a densitometer and (2) without using a densitometer.

A filmstrip exposed in a sensitometer, after having been processed, appears similar to a radiograph of a step wedge; that is, there is a series of density steps. With a densitometer you measure specific density steps of the filmstrip to determine film density, contrast, and base fog. Let's look at a typical filmstrip and see how to determine these factors.

First of all, to measure the density, select a density step between 0.9 and 1.2. These densities are located on the portion of the characteristic curve that is most sensitive to changes in processing. Let's assume the density step that suits our needs is 1.0. This means that every day you measure the density of that same step. The next step is to record the information on a chart like the one illustrated in figure 4-9. Notice on the chart that the density remains near 1.0 and relatively stable until the seventh day, when it begins to drop steadily. Notice also the broken lines at densities of 0.8 and 1.2.

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These lines represent the density variation tolerance, which in most cases should be about 0.2 above and below the normal density. As you can see from the figure, the density has dropped below the tolerance limit, has remained below, and continues to drop. This pattern usually indicates processor problems. Also, you are actually alerted to the existence of a problem on day nine, when the density began to drop. Keep in mind that, on a chart such as this, the trend is the important factor. If a density moves outside the tolerable limit but immediately returns, it probably doesn't indicate a significant problem. A major benefit from using a chart like this is that it alerts you to possible processing problems before the problems affect the radiographs. Thus, you can take the necessary corrective action before a group of radiographs is ruined by the processor. In the case of the processor in figure 4-9, the problem is obviously due to incomplete development, which could be caused by such factors as insufficient replenishment, low developer temperature, or inoperative or insufficient circulation. An increase in density above the tolerance limit indicates such factors as excessive development caused by strong solutions, or high developer temperature. (NOTE: It should be noted that the best way to determine the specific problem with your processor is to refer to the troubleshooting chart supplied by the manufacturer. Possible causes mentioned in this section represent only a portion of the most common ones.) You can also plot densities from film strips of more than one processor on the same chart, as indicated in figure 4-10.

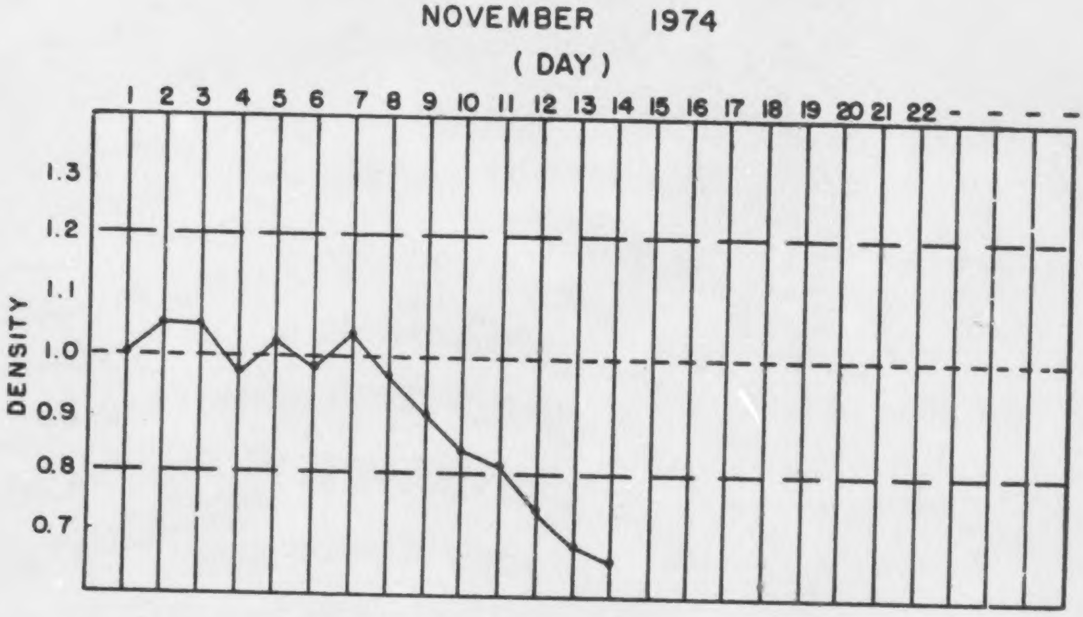


Figure 4-9. Sample chart for recording processor density (single processor).

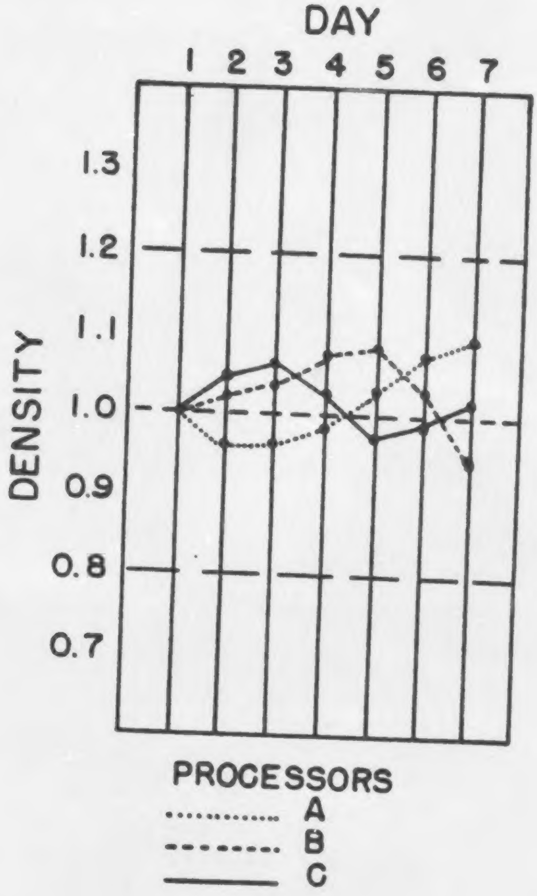


Figure 4-10. Sample chart for recording processor density (three processors).

Exercises (071):

Complete the following exercises based on the chart in figure 4-11.

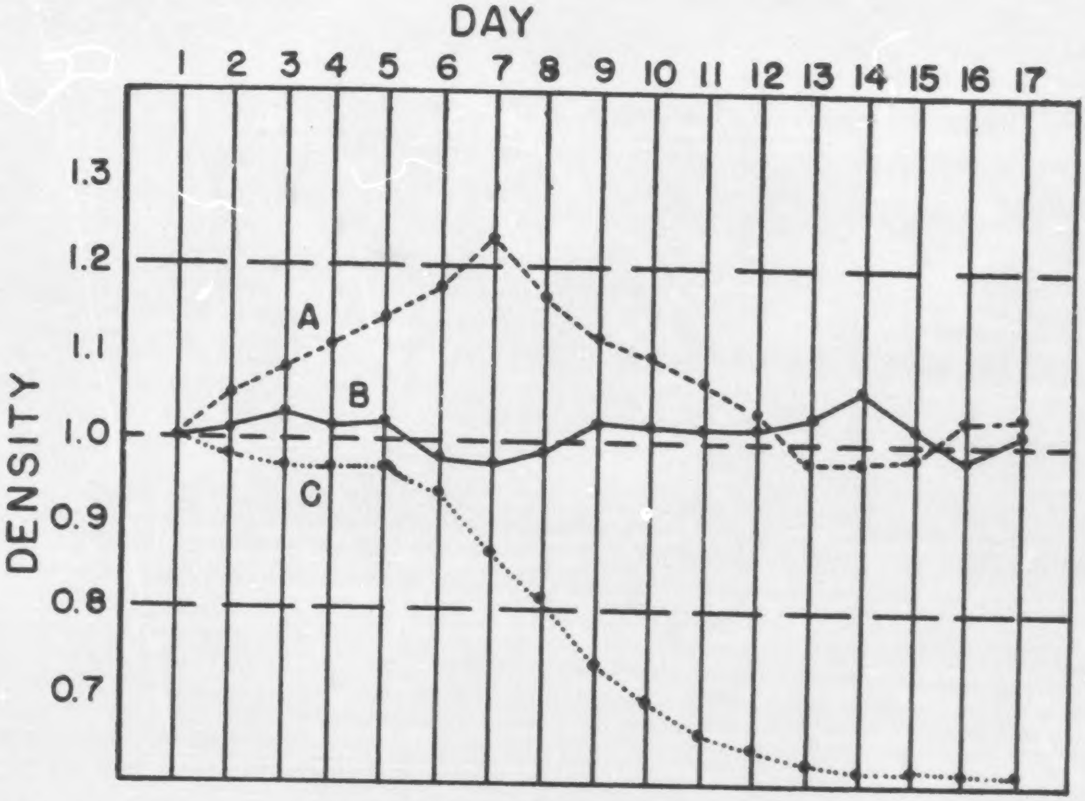


Figure 4-11. Objective 071, exercises 1 through 3.

1. Which processor is the most consistent?

2. Which processor has a significant problem causing underdevelopment? On approximately what day are you alerted to the problem? On approximately what day would you look for a problem with this processor?

3. What would be your thoughts about processor A on days three and four? On day seven? On day 10? On day 17?

072. Given two charts showing contrast and base fog from filmstrips processed in a single processor, interpret the test data and results.

The processor contrast can also be evaluated on a day-to-day basis much the same as the density. To evaluate processor contrast, measure two density steps on the filmstrip. One of the measured steps should be the same step you used to determine the density, as previously described. The other should be a step with greater density, which falls on the upper portion of the slope of the characteristic curve. All you do is subtract the difference between these two densities and plot the results on a chart, as shown in figure 4-12. A tolerance density of about 0.1 should be established. High contrast, shown by greater difference between the two densities measured, can be caused by high developer temperature. After the temperature reaches a certain high point, a further increase in temperature reduces the contrast. Low developer temperature and improper safelighting also reduce the contrast. The effect of developer temperature or contrast is shown in figure 4-13, where the normal developer temperature is 92° F.

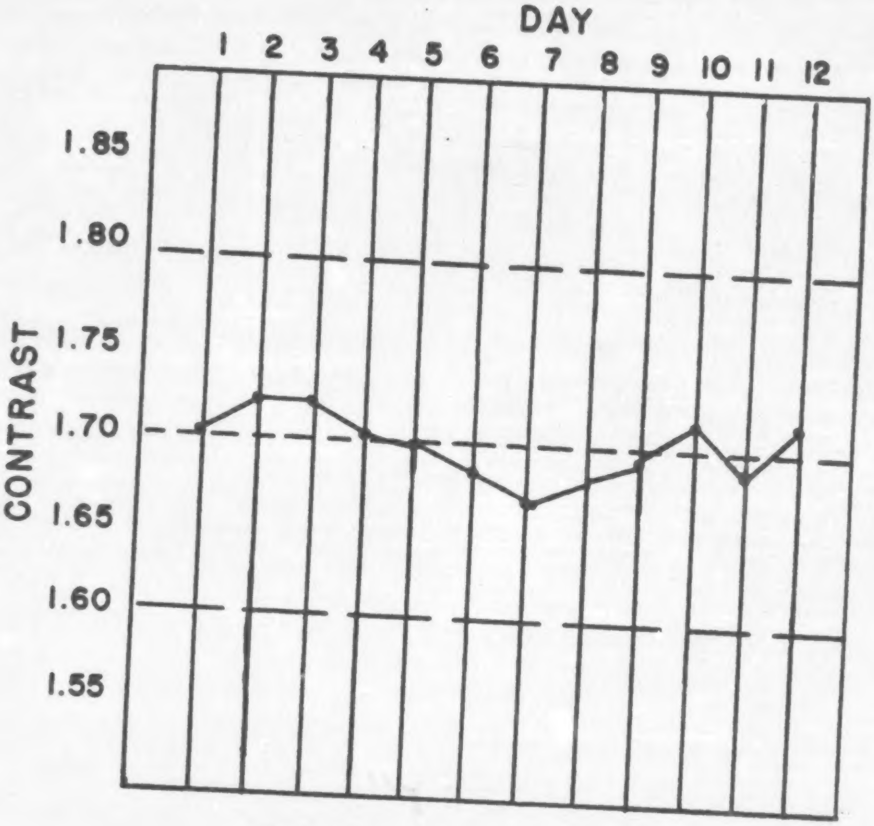


Figure 4-12. Sample contrast chart.

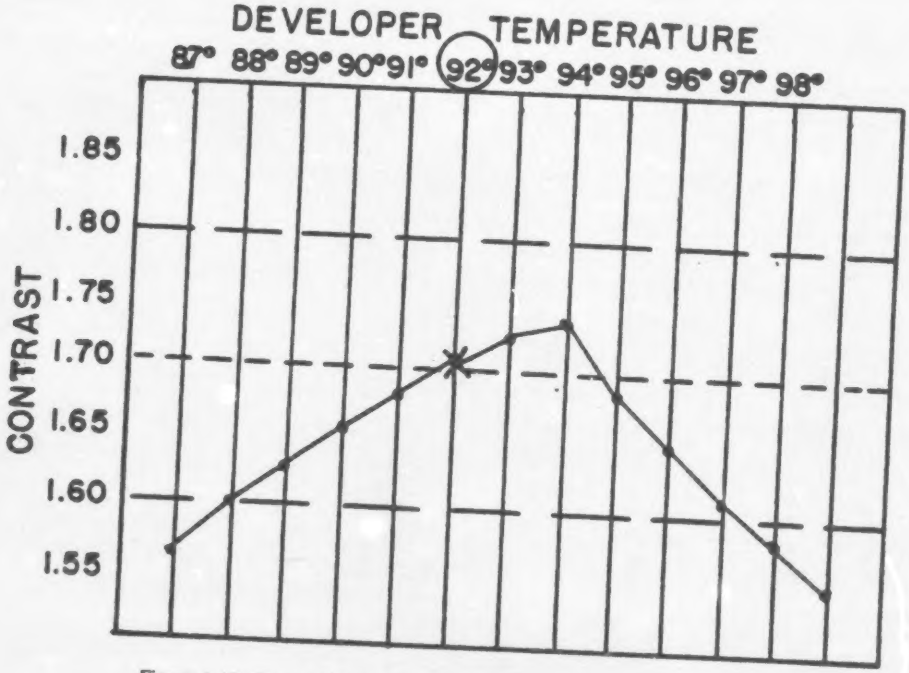


Figure 4-13. Chart showing the effect of developer temperature on contrast.

The base fog of a filmstrip is easily determined by measuring the density of the unexposed density step on the filmstrip. Fog also should be plotted on a chart, as shown in figure 4-14. Base fog should remain consistent. Any appreciable increase should be investigated. (Base fog is never lower than the amount specified by the manufacturer.) High developer temperature increases the base fog. Safelighting conditions also affect fog. Increased exposure to safelights increases the base fog level.

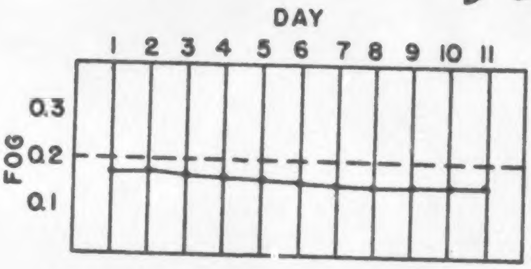


Figure 4-14. Sample chart showing base fog of 0.18.

Exercises (072):

Complete exercise #1 below based on the two charts in figure 4-15. Both charts are of filmstrips processed in a single processor.

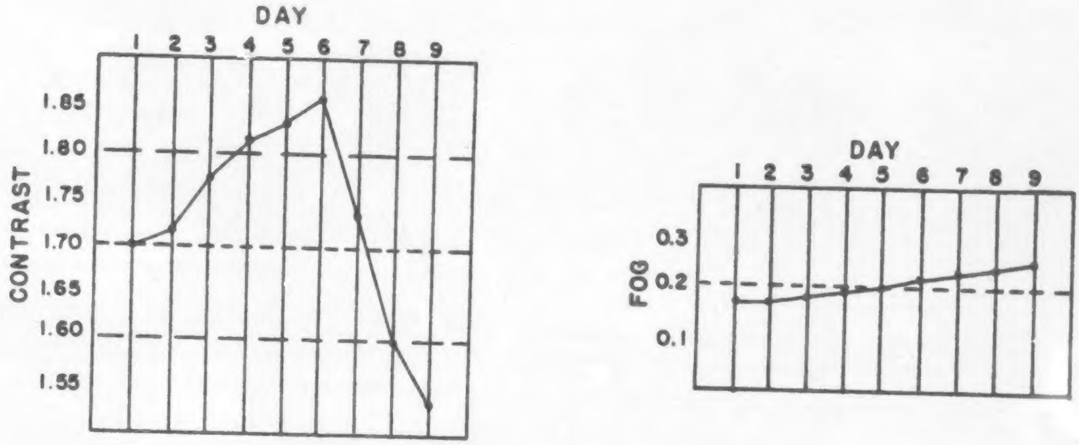


Figure 4-15. Objective 072, exercise 1.

1. Based on the informaion in the text, what is the probable cause of the change in contrast and base fog?

Complete exercise #2 below based on the charts in figure 4-16. Both charts are of filmstrips processed in a single processor.

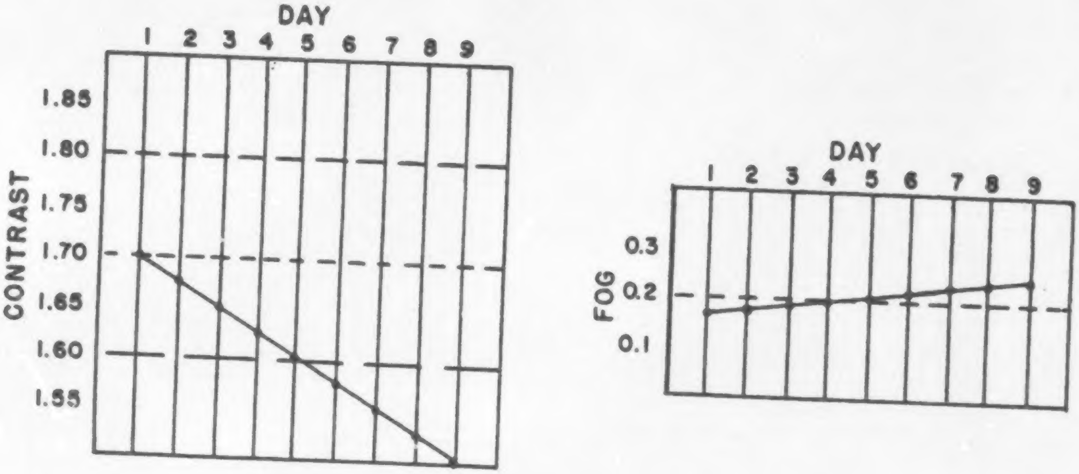


Figure 4-16. Objective 072, exercise 2.

2. Based on the information in the text, what is the probable cause of the change in contrast and base fog?

073. Indicate the disadvantages and procedures involved in the evaluation of processors without using a densitometer.

Up to this point, we have discussed evaluation of processing using a densitometer. You can evaluate your processing without a densitometer; however, you are not likely to spot potential problems as quickly as you would with charted densitometer results. Without a densitometer, simply visually compare the filmstrips with a base strip. Several of the film manufacturers will provide you with a base strip with which to compare your daily strips. By placing the base strip and daily strips side by side on a viewbox, you can make a fairly accurate comparison of the different steps. The most difficult comparison to make is of the contrast, since you must compare the difference between two density steps to the difference between two other density steps. Density and base fog steps are relatively easy to compare since you only have to compare one density step to another.

Exercises (073):

1. What disadvantage results from evaluating processing without a densitometer?

2. Explain how filmstrips are compared.

3. What specific factor is most difficult to evaluate without a densitometer? Why?

074. Interpret a given standardization chart showing the densities of three processors plotted over a 30-day period.

Standardization of Film Processing. Initial standardization of all the processors in your department is as important as daily evaluation of the processing systems. You should be able to process your films (except possibly for special films, such as mammographies) in any processor and obtain approximately the same density in contrast. If you have a processor breakdown and must process those radiographs in another processor, you will quickly realize the importance of standardized processors.

The best way to standardize your processors is to use the density filmstrip test much the same as we described pertaining to daily processor evaluation.

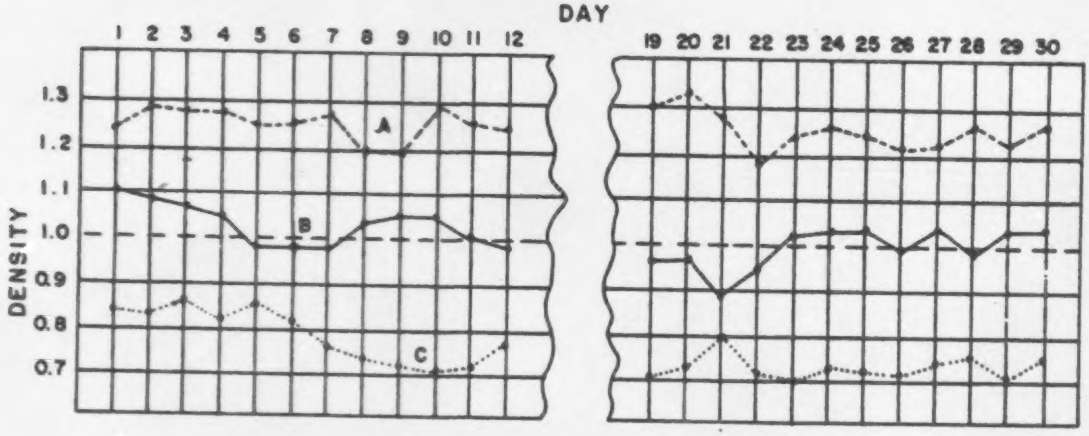


Figure 4-17. 30-day processor standardization chart.

Use the strips and plot the data on charts for approximately 1 month before making any decisions about differences between processors.

To standardize processor density, measure a density step which falls between densities 0.9 and 1.2 as explained before. Plot the results on a chart for 30 days. The average density for the time period should vary no more than 0.2 of the density step, as previously explained. For example, if the density step used is 1.0, the plotted density line should remain between densities of 0.8 and 1.2. In addition, the average densities of different processors should be within a density of 0.2 of each other. Figure 4-17 shows a sample 30-day chart on three processors. Processor B is good. Processors A and B are separated by a density of about 0.5, which is too much variation. A and B are also above and below the 0.2 tolerance respectively; consequently, both of these processors should be aligned so that their density is closer to that of processor A and a density of 1.0.

When you have variations between your processors, such as seen in figure 4-17, there are several things you should check. The first possible cause of the variations is that the processor is not being operated according to the manufacturer's recommendations. Underdevelopment can be caused by such factors as low replenishment rates and low developer temperature. Such factors as high developer temperature and replenishment rates are common causes of overdevelopment. Another possible cause of overdevelopment, with resulting increased density, is high developer immersion time. Immersion time can increase in an automatic processor if the transport gears, rollers, or motor are not operating smoothly. Find out from the manufacturer's brochure what the immersion time should be for your processor. Check the actual immersion time, using a timing device, and note when the leading edge of a film enters and exits the developer solution.

If after checking all the possible causes of processor variation indicated in the manufacturer's brochure, you can find no reason for the variation, increase the developer time slightly to increase the density or decrease the time to decrease the density. Do not make major changes in the developing time without first consulting a processor and chemistry manufacturer's representative for advice.

Exercises (074):

Figure 4-18 is an example of a processor standardization chart, showing the 30-day densities of three processors (A, B, and C). A density step of 1.0 was measured. Based upon the information presented in the text, complete the following exercises:

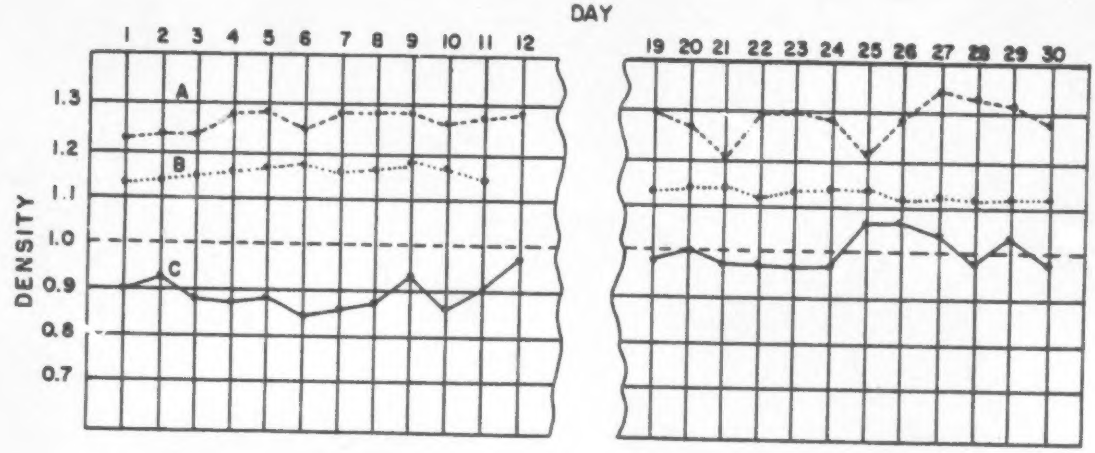


Figure 4-18. Objective 074, exercises 1 through 5.

1. Which processor is likely to produce the lightest radiographs?

2. Which processor(s), if any, shows excessive variation from the measured density step?

3. Are the densities of any two processors separated by more than the maximum allowable amount? If so, which ones?

4. Which processor(s) should be checked for possible problem(s)?

5. When troubleshooting the processor(s) you indicated in exercise #4 above, what are three possible causes of the problem(s)?

CHAPTER 5

Control of Film Quality

IN PREVIOUS chapters of this volume we discussed some of the factors that affect the quality of a radiograph. We discussed such things as the geometrical factors, beam restrictors, grids, and film processing. Now it is time to turn our attention to the exposure factors. Basically, we will be discussing two factors—mAs and kVp. Although we will review some material that you are familiar with, we will concentrate on problems you will face as a quality control technician. We begin this chapter with a close look at density and contrast. Next we discuss the mathematical concepts of exposure and finally exposure systems.

5-1. Density

We have already discussed several factors that control film density, such as intensifying screens, FFD, and film processing. As a general rule, however, these factors, once established, remain constant. We make most of the changes in film density by altering the kVp or mAs simply because it is more convenient to change them than to change the other factors. Keep in mind that this discussion on film density pertains to correcting the initial exposure of a radiograph. In other words, we will deal with things you need to know as a quality control technician.

075. Given a list of statements pertaining to the recognition of radiographs with correct density, indicate which are true and which are false. If you indicate "false," explain your answer.

Acceptable Radiographic Density. Before you can determine whether a radiograph has too little or too much density, obviously you must first be able to recognize the correct density on the radiograph. How do you do this? One way would be to measure the average density on each radiograph with a densitometer. Since an average density of 1.5 is about right for most radiographs, you could easily determine if it is correct by using a densitometer. Of course, we know this is not practical, so we must look for another way.

Density of specific structures. Unfortunately, there is no quick and easy way to learn what a correctly exposed radiograph looks like because there are no clear-cut guidelines. Experience is perhaps the best teacher of all. One important factor is for you to know and recognize the specific structures that should be demonstrated on the radiograph. It is obvious that you cannot evaluate the density of a structure if you cannot first locate it. Let's take an example. An AP radiograph of the lumbar spine and an AP abdomen are taken to demonstrate different structures. Since the spine radiograph is taken to demonstrate the lumbar vertebrae, the density of those vertebrae would be important. But other structures are more important on the abdominal radiograph, such as the renal and psoas shadows, bowel pattern, etc. What all of this means is that evaluation of radiographic density begins with recognition of the structures involved.

Radiologists and density. Another important factor (perhaps we should say "an important person") that must be considered when evaluating film density is your radiologist. Some radiologists like radiographs with more density than do others. In fact, the same radiologist may want different radiographic densities from one examination to another. For example, he may want his skull radiographs a little darker than normal, or his chest radiographs a little lighter than normal. We strongly advise you to sit with your radiologist as he interprets radiographs to learn what he likes and dislikes in terms of density.

Exercises (075):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. The average density on most radiographs should be about 1.5.

T F 2. Experience is not advantageous in recognizing correct radiographic density.

T F 3. Knowing and recognizing specific structures can help you to recognize correct radiographic density.

T F 4. Two identical projections of the same body part may require different densities.

T F 5. Density requirements vary from radiologist to radiologist.

076. State significant features of the procedures for changing the density on a radiograph.

How To Change the Density on a Radiograph. We base our discusion of changing film density on the assumption that minimum amounts of mAs and kVp are necessary to produce a diagnostic radiograph of a particular part. In other words, if too little mAs is used for a skull radiograph, no increase in kVp can compensate. If too little kVp is used, no increase in mAs can compensate.

Let's assume that you have a radiograph with incorrect image density. How do you change the density? As previously mentioned, the most logical factors to change are the kVp and mAs. As a general rule, for most density corrections you should change only one of the factors when possible. This will reduce the posssibility of error, and you will learn through experience how the factors separately affect the radiograph.

Most improperly exposed radiographs in a department that has good technique charts have sufficient kVp or mAs to be diagnostic. In cases such as this, you can either change the kVp or mAs to correct the density. One thing you should always keep in mind is that the way radiographic contrast is affected depends upon what you change. We will discuss contrast later in this chapter.

When evaluating a radiograph to determine how to correct the density, it is a good idea to also consider the kVp and mAs used. By doing this, you are more likely to make the right decision. Let's look at an example. Suppose a radiograph of the skull shows good background density. Good background density can be an indication of sufficient mAs. Further suppose there is not sufficient image density, which means that the structures are too light for clear demonstration. This could be an indication of insufficient kVp. If, after evaluating the exposure factors used, you find the kVp used was below normal, you can almost be certain that more kVp is required. Suppose that in another skull radiograph the structures are demonstrated but are not dark enough, and the background density is insufficient. If a review of the exposure factors shows low mAs, the mAs probably should be increased.

If a radiograph is overexposed, it is usually more difficult to determine the cause. A careful evaluation of the exposure used is often the best course of action. As you no doubt have assumed by now, there are few clear-cut rules to follow with regard to changing the kVp or mAs or both when altering film density. In addition to the information already presented here, the best advice we can give you is to take advantage of every opportunity to learn how kVp and mAs affect a radiograph. If you make a change to improve a radiograph, *check the results*. This will help you considerably. You may even want to keep a log of some of the cases so that you can review them collectively.

Exercises (076):

Answer the following questions or fill in the blank spaces as appropriate.

1. To produce a ________ radiograph you must use a ________ amount of mAs and kVp.
2. To change the density or a particular radiograph you normally should change either ________ or ________, but not ________.
3. Why should you change only one factor to change density?
4. Do good technique charts provide more flexibility in changing density? Explain.
5. Name three factors you should consider when deciding whether to change density with mAs or kVp.
6. Background density can be an indication of sufficient or too little ________.
7. It is easier to determine the cause of an ________ radiograph than the cause of one which is ________.
8. A good way to learn how the changes you make to a technique affect radiographic density is to ________ the ________ of your work.

077. State the basic relationships between mAs, kVp, and radiographic density.

mAs-density relationship. You have no doubt heard many times that you should double the mAs to double the radiographic density and halve the mAs to halve the density. Let's see if this is true. Figure 5-1 shows the characteristic curves of two different X-ray films. Notice in curve A that a change from 1.0 to 2.0 in the density requires a change of from 10 to 18 mAs. In curve B, an increase in mAs from 15 to 48 is required to increase the density from 1.0 to 2.0. As you can see from these two characteristic curves, the rule previously mentioned is not completely accurate. The best way for you to determine what change in mAs will double or halve the density is to refer to the characteristic curve of your particular brand of film. For most X-ray films, the mAs-density relationship is near enough to the previously mentioned rule to use it. Such is the case with curve A in figure 5-1. As a rule, in this CDC we will base the discussions of technique compensations on such films.

It should also be noted that around the shoulder and toe of the characteristic curve the changes in

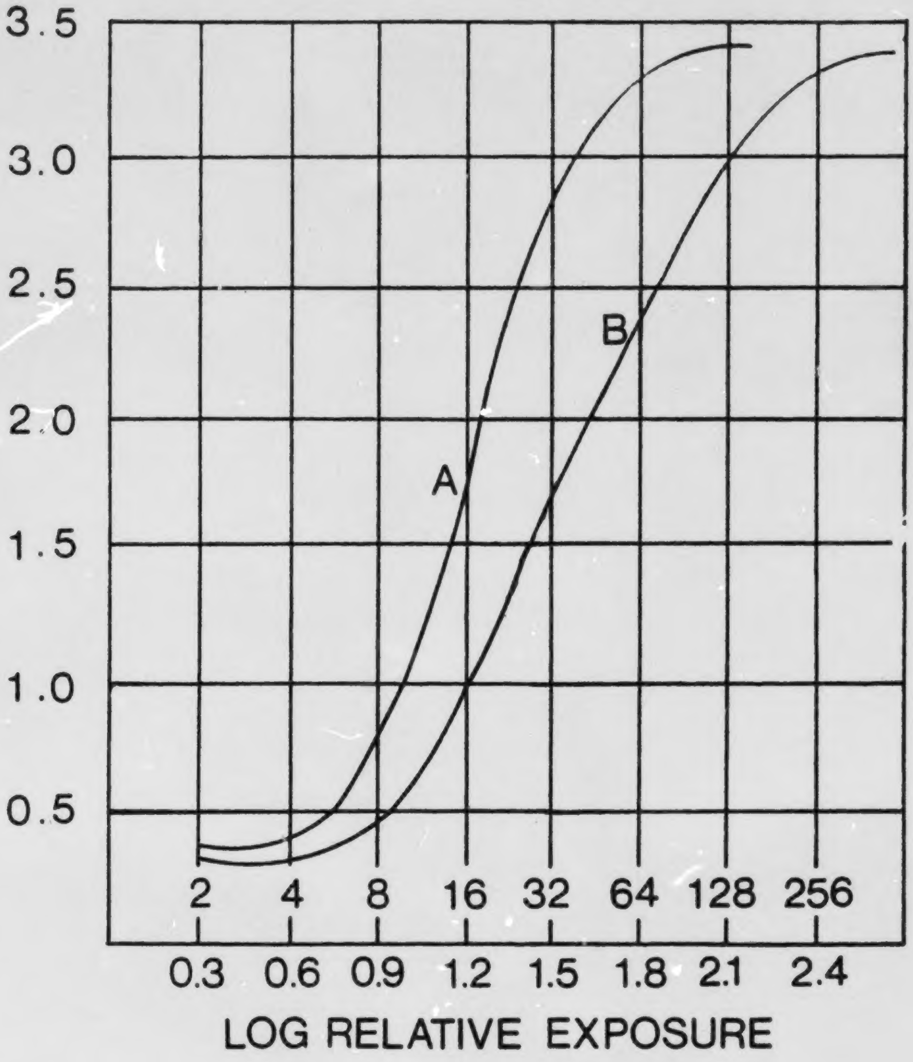


Figure 5-1. Characteristic curves of two different brands of X-ray films.

relative exposure are considerably different from the changes along the slope of the curve. Notice in curve A, figure 5-1, that when a film is very dark, with an average density, for example, of 3.4 halving the mAs (from 128 to 64) reduces the density only by approximately 0.1.

kVp-density relationship. As you know, the characteristic curve of an X-ray film shows the relationship between the mAs and density. Unfortunately it does not reveal the relationship between kVp and density. Therefore, we are left with a rule-of-thumb to follow when we alter the kVp to correct the density on a radiograph. The rule is actually based on the relationship between kVp and mAs. Since we know from our characteristic curve the relationship between mAs and density, we can predict the relationship between kVp and density.

The rule is to add 15 percent of the kVp to double the density and subtract 15 percent of the kVp to halve the density. Subtraction of 15 percent of the kVp represents a decrease of 50 percent in the mAs, and addition of 15 percent of the kVp is the same as doubling the mAs. This rule-of-thumb is based on the assumption that the characteristic curve of your X-ray film is similar to curve A in figure 5-1—that is, doubling or halving the mAs approximately doubles or halves the density.

Exercises (079):

1. How can you determine the *exact* mAs change required to make a specific change in the film density?

2. If the average density on a radiograph is very low (around 0.3), what relative mAs change, compared to a density of 1.5, is required to significantly increase the density?

3. For most X-ray films, how should you alter the mAs to double and halve the average density on a radiograph?

4. For most X-ray films, how should you alter the kVp to double and halve the average density on a radiograph?

5-2. Contrast

Our discussion of contrast includes a definition of contrast, a description of the types of contrast, the factors affecting it, and finally how it is controlled.

078. Define contrast, and given descriptions of three radiographs, compare their contrast properties.

Definition and Types of Contrast. Contrast is defined as "the visible difference in density between the areas or structures on a radiograph." A good example of the absence of contrast is a film that has been exposed to room light and processed. Only one density is present; consequently, there is no contrast. Contrast is classified as either "short-scale" or "long-scale."

Short-scale contrast. If the number of useful densities on a radiograph is small, and the change from one density to another is abrupt, the radiograph is said to have short-scale contrast. This type of contrast is also referred to as high contrast. See figure 5-2.

Long-scale contrast. If the number of useful densities on a radiograph is large and there is little change from one density to another, the radiograph is said to have long-scale contrast. This type of contrast is also referred to as low contrast. See figure 5-3.

Relative properties of contrast. You should realize by now that there is no definite line separating the two types of contrast. Contrast is a relative measure of the difference between densities on a radiograph. A particular radiograph may exhibit short-scale contrast when compared to another, but its scale of contrast may be long when compared to a third radiograph.

Figure 5-2. Short scale or high contrast.

Exercises (078):

1. Define radiographic contrast.

Suppose there are three radiographs of the same part with different scales of contrast. Eleven different densities can be seen on radiograph A with little change from one density to the next. Only five different densities can be visualized on radiograph B with considerable change from one density to the next. Radiograph C shows eight different densities with proportional changes between densities. Based on the information presented in the text, answer exercises 2 through 6 below.

2. Which of the three radiographs has the lowest contrast?

3. Which of the radiographs has the highest contrast?

Figure 5-3. Long scale or low contrast.

4. In comparison of radiographs B and C, which exhibits long-scale contrast?

5. In comparison of radiographs A and C, which exhibits long-scale contrast?

6. In comparison of radiographs A and C, which exhibits short-scale contrast?

079. Correlate structure thickness, atomic number, and density with radiograph contrast.

Factors Affecting Contrast. There are three major factors that affect radiographic contrast—film contrast, subject contrast, and film fog. Film contrast is a photographic property of the X-ray film itself and is evaluated by referring to the characteristic curve, as discussed in chapter 4. So we begin our discussion with subject contrast, and conclude with film fog.

Subject contrast. Subject contrast depends upon the selective absorption of X-ray photons. When a beam of X-radiation is directed toward a body region, such as the chest, some parts of the region absorb more X-ray photons than do others. For example, the heart absorbs more photons than does the lung tissue. Consequently, the parts of the film beneath the lung tissue receive more photons and when processed appear darker than the heart. This difference in absorption by various body parts is called selective absorption and results in different densities, or contrast, on a radiograph. Several factors affect the selective absorption of photons and consequently the type of radiographic contrast. The first factor we will discuss is the difference between thicknesses of structures:

a. If three structures, identical except for thickness, are interposed between an X-ray tube and film, the thicker structure absorbs more X-ray photons, as shown in figure 5-4. An example of this is an AP radiograph of the leg. The fibula, which is thinner than the tibia, absorbs fewer photons than does the tibia. Consequently, the fibula appears a little darker on the radiograph. The greater the difference in part thickness, the greater the difference in the densities appearing on the radiograph—or the higher the contrast.

b. The atomic numbers of the various structures also affect the selective absorption of photons. The greater the difference between the atomic numbers, the greater the absorption difference—consequently, the higher the contrast on the radiograph. The reason for the difference in absorption is that the higher the atomic number, the

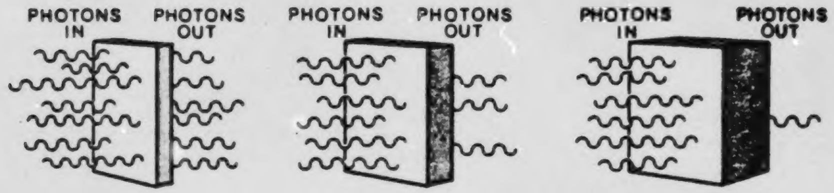


Figure 5-4. Comparison of the difference between absorption of photons by structures with different thicknesses.

greater is the absorption because of the photoelectric effect. The atomic numbers for bone, muscle, and fat are approximately 12, 7.5, and 6 respectively. You can see why there is relatively high contrast between bone and muscle or between bone and fat, while there is relatively low contrast between muscle and fatty tissue.

c. The difference between the densities of structures is another factor that affects the selective absorption of photons. By "density" we mean the number of atoms per unit area. The greater the difference between the densities, the greater the difference in absorption—consequently, the higher the radiographic contrast.

Exercises (079):

1. Generally speaking, how do these three factors—structure thickness, atomic number, and density—affect the contrast on a radiograph?

2. Suppose you take two AP radiographs of the leg (tibia and fibula)—one of the proximal leg and one of the distal leg. With all other factors remaining the same, on which radiograph would there be less contrast between the tibia and fibula? Why?

3. If you take a radiograph of a part containing muscle, fat, and bone, which of the three structures absorbs the most photons? The least? Why?

Three radiographs are made. Radiograph A shows bone and muscle, radiograph B shows bone and fatty tissue, and radiograph C shows muscle and fatty tissue. All other factors, kVp, and thickness of structures are equal. Based on the information in the text, answer exercises 4, 5, and 6 below.

4. Which radiograph exhibits the highest contrast?
5. Which radiograph exhibits the lowest contrast?
6. The less the difference between structure density, the ________ the contrast on the radiograph.

080. Given descriptions of three radiographs, determine the relative kVp used for each and select the one exhibiting the highest contrast.

The most important factor to you—most important because you have direct control—that affects the selective absorptions of photons is the penetrative ability of the primary beam. Whether we say "penetrative ability" or "wavelength" or "energy," it all boils down to the kVp selected on the control panel.

Let's see how kVp affects the selective absorption and contrast on a radiograph. Figure 5-5 shows two equal parts, exposed to two different beams of X-radiation. As shown, 10 photons approach each step. Suppose that at 40 kVp 2 photons reach the film beneath step #1, and 5 photons reach the film beneath step #2. This would mean that step #1 transmits 40 percent fewer photons than does step #2. If the kVp is increased to 80, more photons penetrate both steps as shown, but there is a greater increase in the transmission through step #2 than in step #1. We show four photons reaching the film through step #1 and nine photons through step #2. In this case, step #1 transmits 44 percent fewer photons than does step #2. This percentage change in the selective absorption of photons results in a proportionate change in the contrast on a radiograph.

The specific type of contrast that high or low kVp produces should also be obvious to you by now. Refer again to figure 5-5. If we consider the density of each step on the film to be a result of the number of photons transmitted through the step, there would be a greater difference between the densities of the steps at 40 kVp than at 80 kVp. This greater difference, of course, means higher contrast.

Exercises (080):

Three radiographs are made of a chest, using 50, 80, and 100 kVp. The mAs is varied to compensate for the kVp difference, and all other factors remain the same. The densities of the ribs and the lung tissue are as follows:

Radiograph A - rib density 1.0 - lung density 2.7
Radiograph B - rib density 1.2 - lung density 2.3
Radiograph C - rib density 1.5 - lung density 1.8

Based on the information presented in the text and the above data, complete the following exercises.

1. With which radiograph was the 100 kVp used?
2. With which radiograph was 80 kVp used?
3. With which radiograph was 50 kVp used?
4. Which radiograph exhibits the highest contrast between the ribs and lungs?

081. Define "film fog," and indicate the effect of film fog on radiographic contrast.

Fog. Film fog—whether caused by scatter radiation, by improper processing, or by exposure of the film to either light or to radiation leaks—reduces contrast on a radiograph. Since we have previously discussed ways to reduce film fog in other chapters of this volume, our discussion here is limited to an explanation of what fog is and of how it affects contrast and demonstration of certain structures.

"Film fog" is a density on a radiograph that is not caused by deliberate film exposure. Ideally, image density and the variations in image density (contrast) are caused by selective absorption of X-ray photons. Fog density, on the other hand, is not selective in nature. It usually appears evenly distributed over the entire film.

Because of its even distribution, the fog on a radiograph completely obscures some structures and makes others difficult to see. To illustrate how fog affects a radiograph, figure 5-6 shows three drawings, representing radiographs of a step wedge. Drawing A shows no appreciable fog. Drawing B represents the addition of a layer of density. Drawing C shows yet another layer of density. If you compare the three drawings, you can see how the contrast has been lowered. Notice also that some steps that were easily distinguished in drawing A begin to "disappear" as fog is added. A good example is the loss of contrast between steps 4 and 5 in drawing C. You can no longer see any contrast between the two. The reason the structures disappear is that once a certain density is reached, our eyes can no longer pick up differences between densities.

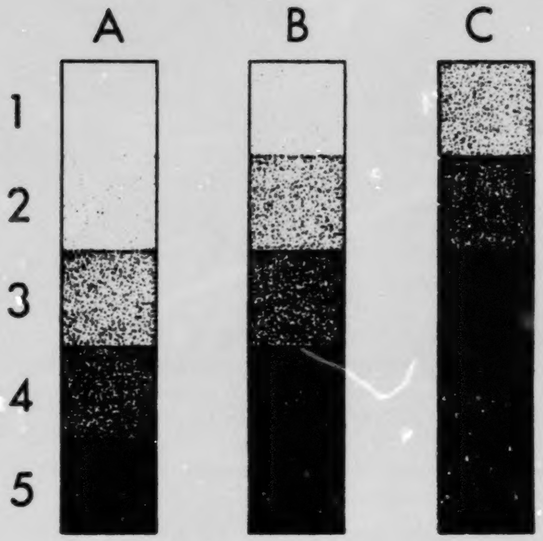


Figure 5-6. The effect of fog upon contrast and visualization of structures.

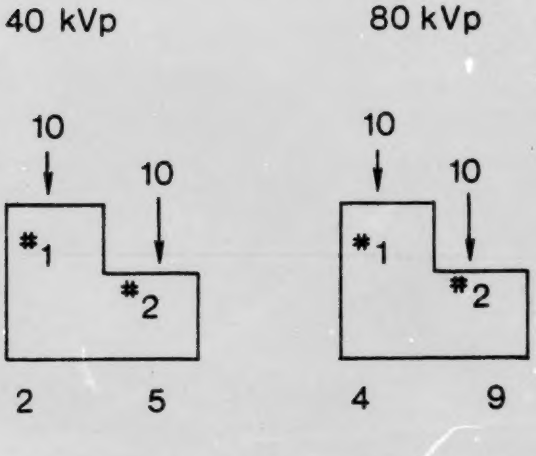


Figure 5-5. Illustration showing how kVp affects the selective absorption of X-ray photons.

Exercises (081):

1. What is film fog?

2. Specifically, how does the addition of fog affect the contrast on a radiograph?

3. How can the addition of fog to a radiograph cause some structures to disappear?

082. Given the kVp and mAs values used on a radiograph, change the factors to both raise and lower the contrast of the radiograph.

How to Change Contrast on a Radiograph. There are times when your radiologist wants a "properly exposed" radiograph repeated with more, or with less, contrast. By "properly exposed," we mean the radiograph has the correct average density. You should realize by now that to change the contrast, you should change the kVp—increase the kVp to lower the contrast and lower the kVp to increase the contrast. In addition, you must make a compensatory change in the mAs to maintain the correct density.

You may have heard in the past that you can increase the kVp by 10, halve the mAs, and end up with two radiographs equal in overall density. This "rule" is based on the assumption that density changes on a linear scale if changes are made in the kVp. This assumption is inaccurate. Changes in density resulting from changes in kVp are nonlinear. Therefore, to make a specific change in film density by changing the kVp, you must use a percentage of the kVp.

A good rule of thumb to follow is to increase the kVp by 15 percent and halve the mAs or lower the kVp by 15 percent and double the mAs. For most brands of radiographic film, these changes will maintain the same approximate density on a radiograph while changing the contrast.

Exercises (082):

A radiograph is made using 80 kVp and 40 mAs. Use this data and the information presented in the text to complete the following exercises.

1. What would be the new mAs and kVp if the contrast needs to be lowered?

2. What would be the new mAs and kVp if the contrast needs to be raised?

5-3. Mathematical Concepts of Radiographic Exposure

It would be convenient if we could use the same exposure factors for each examination. For example, if all skull radiographs were performed on patients who could cooperate and maintain the positions with ease, we would have few problems. But we know that it doesn't happen that way. We often radiograph skulls on patients who are seriously injured, or on patients intoxicated to the point where they cannot cooperate, or even on small children. For some of these patients we must change from our routine exposure factors to prevent part motion. Although this section is short, the information should enable you to make compensations to your exposure (mA, mAs, sec, or FFD) by calculation, rather than by guesswork.

083. Apply the mA-sec formula to two sets of exposure factors and calculate the new mA if the exposure time is changed and calculate the new exposure time if the mA is changed.

mA and Exposure Time. As you know, mA and exposure time directly influence radiographic density. The time of exposure, however, has additional significance when patient motion, either voluntary or involuntary, must be controlled to obtain optimum detail. Motion is one of the greatest deterrents to good radiographic detail. Whether the motion is voluntary, as in pediatric cases, controlled, as in respiration,—or involuntary, as in peristalsis of the organs (ureters or bowel), beating of the heart, or muscle spasms—you must consider motion when you select the exposure factors to be used. The correct combination of sec and mA is one of your most effective means of controlling undesirable motion and thus enhancing image detail.

Expressed mathematically, the mA-sec relationship is $mA_1 : mA_2 :: sec_2 : sec_1$. To maintain a given film density, the mA required is inversely proportional to the time of exposure, when all other factors are kept constant.

Now let's apply this to a working situation. Suppose your standard technique for a lateral skull is 100 mA at 1/10 sec. Further, suppose there is a change from the normal working situation; for example, that as a result of trauma received in an automobile accident, the patient is semiconscious and unable to cooperate fully. Motion due to respiration and possibly to muscle spasm has become a factor to consider. In an effort to reduce this motion, you can reduce the normal exposure time. Let's say you want to reduce the exposure time to 1/20 sec. By applying the mathematical formula for mA and sec, you are able to derive the new mA required. Consider the following:

$$mA_1 : mA_2 :: sec_2 : sec_1$$

$$100 : x :: 1/20 : 1/10$$

$$1/20\ x = 10$$

$$x = 200$$

Consequently, your new mA is 200.

You can also find your new exposure time if, for example, you want to change the mA station. Use the same formula stated above.

Exercises (083):

1. Suppose your technique chart calls for 50 mA and 1/10 sec for a particular radiograph. Your patient is uncooperative and you wish to use 1/30 sec. What is your new mA?

2. Suppose your technique chart calls for 600 mA and 1/40 sec and you wish to use the small focal spot that has a 150 mA output. What is your new exposure time?

084. Applying the appropriate formula to five sets of exposure factors, determine the new mAs, mA, exposure time, or FFD.

FFD and Density. As we have discussed before, X-rays diverge from the focal spot, traveling in straight lines. Thus, the X-ray beam covers an increasingly larger area as the FFD increases and vice versa. This change in field size, however, results in a change in the number of photons per unit area, providing all other factors remain constant. When FFD increases, radiographic density decreases; and as the FFD decreases, film density increases. In order to maintain the desired density, then, the quantity of radiation *produced* can be manipulated to compensate for changes in FFD. Since mAs controls the total quantity of X-rays produced, appropriate changes in this factor can be made to maintain film density and compensate for changes in FFD.

This proportional relationship between mAs and FFD can be best expressed in a mathematical formula, which is referred to as the *mAs-distance formula.* A verbal reading of the formula would be: The original mAs (mAs_1) to the new mAs (mAs_2) as the original FFD squared (FFD_1^2) is to the new FFD squared (FFD_2^2). You can determine any one of the four factors by using this formula.

A practical application of this formula is as follows: Suppose the technique chart normally specifies a technique of 10 mAs using a 72-inch FFD; however, because of equipment limitations and the patient's condition, you are unable to obtain the recommended FFD, but instead must use a 36-inch FFD. What new mAs factor will be required to maintain the original film density? Let's substitute the known technique values into the formula:

$$mAs_1 : mAs_2 :: FFD_1^2 : FFD_2^2$$

$$10 : x :: 72^2 : 36^2$$

$$10 : x :: 5184 : 1296$$

$$5184\,x = 12960$$

$$x = 2.5$$

Therefore, your new mAs would be 2.5.

Since mAs is the product of mA times exposure time, this same formula represents the mA-distance or time-distance relationships. All you have to do is to substitute mA or seconds for the mAs and proceed as usual with the formula. Although you will have to use the mAs-distance formula to determine certain technique changes, you can make a few changes without using the formula. Just keep in mind that twice the distance requires four times the exposure, and that half the distance requires one-fourth the exposure.

Exercises (084):

1. What will your new mAs be if your original mAs was 12.5 at a 40-inch FFD and you wish to change the FFD to 48 inches?

2. If your technique chart calls for 10 mAs at a 40-inch FFD and you wish to reduce the mAs to 2.0, what is your new FFD?

3. Suppose your technique chart calls for 1/60 sec at a 36-inch FFD and you wish to change your time to 1/40 sec. What is your new FFD?

4. What will your new mA be at a 36-inch FFD if your old mA was 100 at a 72-inch FFD?

5. What is your exposure time at a 36-inch FFD if at 72 inches it is 1/5 sec?

5-4. The Standardization of Exposure Techniques

In order to insure consistent film quality and to provide accurate guides for the selection of all exposure techniques, each radiology section should have a standard system of exposure factors. The establishment of such a system is one of the greatest challenges confronting technicians, although it is a problem that could be solved easily if a universally correct exposure technique for each part could be prescribed. But, unfortunately, a universal technique is not possible because of several variables, including the output and the capacity of X-ray machines, the types of exposure devices, the speeds of films and screens, and the preferences of radiologists. Because of these variables, you must be able to prepare and correct your own standard system of exposure factors. This section is intended to help you do so.

085. Name four requirements of an exposure system and explain how each is met.

Requirements of a Standard Exposure System. A standard system of exposure techniques must meet these four basic requirements: (1) it must produce consistent results; (2) it must provide adequate exposure of the film; (3) it must possess a certain degree of flexibility; and (4) it must provide for the desired range of contrast.

Consistent results. One requirement of an exposure system is that it must produce consistent results. By consistent results we mean, for example, that two chest radiographs taken of the same patient 2 months apart will appear the same—the same contrast and density. This is very important in cases where followup radiographs are performed to check progression or regression of pathological conditions.

To produce consistent radiographs from one day to the next, you must have technique charts unless you are the only technician in your department and have a "pushbutton" memory. In addition, all technicians in the department must *use* the charts. The purpose of technique charts is defeated if some technicians are allowed to use their "own" techniques.

Sufficient exposure of film. In order to produce satisfactory density, a technique must provide for adequate exposure of the film. This requires proper selections of both mAs and kVp. First, there must be enough radiation in the primary beam to create silver deposits on the film. Therefore, a minimum mAs value must be established for each part. Secondly, if the primary radiation is to reach the film, the part must be adequately penetrated. Even though the quantity of the beam is sufficient, the image cannot be projected on the film if the part absorbs too much or all of the primary beam. It follows that a minimum kVp value must also be established for each part.

Flexibility. Because exposure techniques must be frequently changed to compensate for the conditions of patients, for differences in accessory devices, and for other factors, a system of exposure techniques should be reasonably flexible. For example, a basic technique selected at the highest kVp on your control panel would not permit an increase; and on the other hand, a technique selected at the minimum kVp would not permit a reduction. This means that the mAs and the kVp must be kept within a range from which either may be increased or decreased.

Desired contrast range. Any system of techniques must be able to produce the preferred range of contrast within the capabilities and limitations of the machines and other equipment. Of course, the kVp range is the basic determining factor here.

Exercises (085):

In exercises 1 through 4 below, name four requirements of an exposure system and tell how you can help insure that each requirement is met.

1.

2.

3.

4.

086. Cite specific facts about variable kVp techniques.

Types of Exposure Systems. In modern radiography three basic types of exposure systems are in general use: variable kVp techniques, fixed kVp techniques, and high kVp techniques, which can be classified as variable or fixed kVp.

Variable kVp techniques. Under the variable kVp techniques system, the mAs remains constant for each part, and the kVp is varied according to part thickness in centimeters. For this reason, it is sometimes referred to as a tissue-thickness technique. One disadvantage of this exposure system is that the contrast varies slightly because the kVp changes from one examination to another. However, it is a popular system and relatively easy to apply.

Let's see how to build a variable kVp technique chart. Suppose you decide that for an average-sized adult 20 mAs is sufficient to produce adequate exposure of the film and in combination with the necessary kVp produces the desired scale of contrast. All you need do is to determine the kVp for each centimeter thickness of the skull. For example, suppose you determine by trial and error that the exposure factors of 20 mAs and 80 kVp produce the desired density and contrast for a PA skull that measures 18 cm along the CR. Chart all the information on a working chart. From this starting point, you can perhaps establish the kVp/centimeter relationship for other measurements of the skull. You may have to add or subtract 2 kVp for each centimeter change. If so, you would use 82 kVp for 19 cm, 78 kVp for 17 cm, and so on. Keep in mind that the centimeter measurement is through the path of the CR for each projection of the skull.

The two kVp change for each centimeter of part thickness given in the example above may or may not work for some body parts. Usually, kVp changes of from one to four are made, depending upon the part and the kVp range—the greatest change per centimeter is required when high kVp is used and for denser parts.

Once you determine the correct exposure factors for each part, construct a technique chart, post it near the control panel, and insist that everyone use it. Any type of chart can be constructed as long as it provides the necessary information. Figure 5-7 shows how the example we discussed might look on a technique chart.

You can also construct a *plus factor* technique chart that permits you to determine the correct kVp without referring to the chart for every measurement. Let's take our example of the skull again. Eighty kVp is used for 18 cm. Multiply the cm thickness by two—which gives you 36. Subtract 36 from 80 (your kVp at 18 cm). This gives you a plus factor of 44 for all projections of the skull. Now when you measure the CR for a projection of the skull, all you have to do is double the cm thickness, add the plus factor, and you have your kVp. Expressed as a formula, the plus factor-kVp relationship for this example looks like this:

$$\begin{aligned} kVp &= 2 \times \text{cm} + 44 \\ &= 2 \times 18 + 44 \\ &= 36 + 44 \\ &= 80 \end{aligned}$$

Keep in mind that the plus factor is determined from a good working exposure and may vary from part to part.

Exercises (086):

Complete the following exercises pertaining to variable kVp techniques by filling in the blank spaces with one word or by answering the questions, as appropriate.

1. The same ________ is used for each part.
2. What determines the kVp for each radiograph?

3. What is a disadvantage of this type of exposure system?

4. Give one advantage of this exposure system.

5. How do you determine the starting technique for a given measurement of a part?

6. When you vary the kVp for parts larger or smaller than average, a kVp change from ______ to ______ per centimeter is usually necessary.
7. What is the advantage of using the plus factor to determine kVp?

8. What is the kVp for a projection if the part measures 20 cm and the plus factor is 38?

9. What is the plus factor for an examination if 64 kVp is used for 12 cm?

087. Given a list of statements pertaining to fixed kVp techniques, indicate which are true and which are false. If you indicate "false," explain your answer.

Fixed kVp techniques. An exposure system that is rapidly becoming more popular involves fixed kVp techniques. Under this system, the kVp remains constant for a particular part, while the mAs is varied. The kVp is established on the basis of its satisfactory penetration of that part. The mAs is selected to provide satisfactory density for each part, according to its average thickness in centimeters. For parts smaller or larger than the average, the mAs is varied—generally, it is raised or reduced in increments of 25 percent. Fixed kVp techniques, when properly corrected and worked out to the desired mAs refinements, have one outstanding advantage: they provide consistent contrast for all examinations of a particular part because the kVp is constant. The one major disadvantage is the amount of time and effort it takes to prepare these techniques. In order to establish the mAs selections, it is necessary to keep accurate records of all radiographs; the record of each should indicate the exposure factors used, the part thickness, and the results of the exposure. Only in this way can techniques be corrected and

Part	Projection	Grid	Screens	FFD	MAs		CMS/kVp												Remarks
Skull	All	12:1	Hi-Speed	40"	20		3/70	14/72	15/74	16/76	17/78	18/80	19/82	20/84	21/86	22/88	23/9		Measure CR

Figure 5-7. An example of technique chart format.

finalized. Weeks, perhaps months, are required to do this.

Exercises (087):

Indicate whether the following statements pertaining to fixed kVp techniques are true or false. If you indicate "false," explain your answer.

T F 1. kVp is constant for each part.
T F 2. mAs varies depending upon the size of the part.
T F 3. A change from 40 to 50 mAs for a larger part is appropriate.
T F 4. Contrast is consistent for all body parts.
T F 5. These techniques are easy to prepare.

088. Explain what is meant by high kVp techniques, and list three advantages of their use.

High kVp techniques. High kVp techniques are basically high kVp-low mAs exposures and can be applied to either variable kVp or fixed kVp exposure systems. How high is high kVp? Actually it depends upon whom you ask. The best explanation of the matter is that high kVp is the highest kVp you can use and still produce good diagnostic radiographs that satisfy your radiologist. It could be 80 kVp for one examination and 120 for another.

High kVp is used in many radiology departments for the following reasons: (1) there is less absorption of photons by the patient, (2) the target of the X-ray tube is subjected to fewer heat units per exposure, and (3) there is greater exposure latitude.

Exercises (088):

1. What are high kVp techniques?

2. List three advantages of high kVp techniques.

089. Given various specific situations when it is necessary to make changes in the exposure to compensate for factors such as use of a different grid, use of an extension cylinder, the presence of a cast, or patient's age, specify the change in exposure factor to be made.

Compensating Factors. No exposure system is complete without a list of compensation factors to apply when you must make changes in the exposure because of a different grid, the presence of a cast, the use of an extension cylinder, or the patient's age. Table 5-1 shows these compensation factors.

Exercises (089):

Complete the following exercises, stating the compensation factor to be used in each specific situation.

1. If your kVp is 75 with a 8:1 grid and you wish to change to a 5:1 grid, what is your new kVp?

2. If your kVp is 92 with a 5:1 grid and you wish to change to a 12:1 grid, what is your new kVp?

3. If your kVp is 120 with a 16:1 grid and you wish to change to a 5:1 grid, what is your new kVp?

4. If a cast was applied to a patient's leg 18 hours ago, how much mAs should you use on the leg if the mAs without the cast is 10?

5. By what percentage should you increase the mAs when using an extension cylinder?

6. What percentage of the adult mAs should you use for the following patients?
   a. Birth to 1 year.
   b. Six to 9 years.
   c. Over 55 years.

TABLE 5-1

COMPENSATING FACTORS

Compensation Factors for Grid Changes

Grid Change	*Conversion*
Nongrid to 5:1	Increase kVp by 5%
Nongrid to 8:1	Increase kVp by 10%
Nongrid to 12:1	Increase kVp by 15%
Nongrid to 16:1	Increase kVp by 20%
5:1 to 8:1	Increase kVp by 5%
5:1 to 12:1	Increase kVp by 10%
5:1 to 16:1	Increase kVp by 15%
8:1 to 5:1	Decrease kVp by 5%
8:1 to 12:1	Increase kVp by 5%
8:1 to 16:1	Increase kVp by 10%
12:1 to 5:1	Decrease kVp by 10%
12:1 to 8:1	Decrease kVp by 5%
12:1 to 16:1	Increase kVp by 5%
16:1 to 5:1	Decrease kVp by 15%
16:1 to 8:1	Decrease kVp by 10%
16:1 to 12:1	Decrease kVp by 5%

Compensating Factors for Casts

Wet cast (cast applied up to 12 hr.)	3.5 times mAs or 16 to 20 kVp
Dry cast (anything over 12 hr.)	2.0 times mAs or 10 to 14 kVp

Compensating Factors for a Cylinder

Adding a cylinder	Increase mAs by 20%
Removing a cylinder	Decrease mAs by 20%

Compensating Factors for Age Difference

Birth to 1 yr.	Use 30% of the adult mAs
2 to 5 yr.	Use 60% of the adult mAs
6 to 9 yr.	Use 70% of the adult mAs
10 to 12 yr.	Use 90% of the adult mAs
55 yr. and older	Use 75% of the adult mAs

CHAPTER 6

Environmental Safety

AS AN X-RAY TECHNICIAN you operate elaborate electrical as well as radiation-producing equipment. This equipment, if not operated properly, can be extremely dangerous to you and to your patients. In this chapter, we will define some of the specific problem areas associated with electrical and radiation hazards. We will also provide solutions where possible to help you prevent electrical shock and overexposure to ionizing radiation to you and your patients.

This chapter consists of four sections. The first section pertains to electrical hazards and protection. In the second section we will discuss radiation hazards and protection for the patient. After that, ways to protect you, the technician, will be covered. Finally, we will discuss the USAF Film Badge Program.

6-1. Electrical Hazards and Protection

As you know, radiology departments are full of electrical devices—from the viewing room to the darkroom to the exposure room. Where electrical devices are present, so is the possibility of an electrical fire or electrical shock. You can help reduce electrical hazards by using commonsense and following recommended safety precautions. Let's begin our study of electrical hazards and protection with a discussion of four factors affecting the severity of an electrical shock.

090. Name and explain briefly four factors affecting the severity of electrical shock.

Factors Affecting Severity of Electrical Shock. Electrocution, as performed in prisons, uses about 9 amperes. Obviously, this amount is far more than the minimum needed to cause a lethal shock. What is the minimum amount of current required to electrocute a person? The amount varies considerably because there are at least four important factors involved:

a. The person involved and his state of health. An elderly person or one in poor health is more apt to experience the effects of electrical current.

b. The part of the body involved. Vital organs, in particular the heart or brain, are more susceptible to electrical current than are, for example, the legs and arms.

c. The time of exposure. The length of time the person is exposed is also an important consideration. Obviously, the longer the exposure, the greater the effect.

d. The type of current. DC is more dangerous than AC. As a general rule, we are concerned with AC in our radiology departments although DC is present in some instances.

Exercises (090):

In exercises 1 through 4 below, name and briefly describe four factors affecting the amount of current which can cause electrocution.

1.

2.

3.

4.

091. Given a list of statements pertaining to the use of fuses, indicate which are true and which are false. If you indicate "false," explain your answer.

Fuses. As you know, a fuse is a protective device. What does it protect? Not you. Not your patient. It protects the circuit. It is simply a device that will "burn out" and stop the flow of current when the maximum rating of the fuse is exceeded. Because of this, we can also say a fuse protects the equipment or structure from damage due to high current or fire. The size of a particular fuse is based upon the amount of current in amperes that the circuit is designed to handle; for this reason, it should not be replaced with a fuse of higher rating.

A typical experience. Let's look at a situation that perhaps occurs all too often. A 15-ampere fuse blows in your home. You replace it—and it blows again. This time you replace it with one rated at 25 amperes. Good—the 25-ampere fuse doesn't blow, and all is well, at least for the time being.

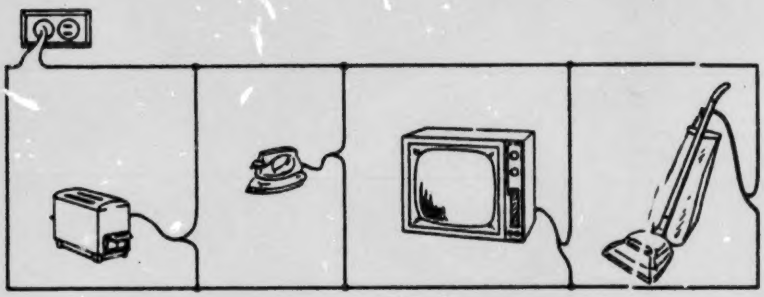


Figure 6-1. Pictorial drawing of an electrical circuit.

A few weeks later, it's a rainy weekend and a good time to get some work done around the house. Your wife is ironing, one child is watching TV, another is using the toaster, and you are using the vacuum cleaner. Suddenly the house is on fire. You barely manage to get everyone out of the burning house. As you watch your home go up in flames, you ask, "What happened?"

Let's investigate. Figure 6-1 is a picture of the electrical circuit at the time the fire started. Figure 6-2 is a schematic of that circuit. Since we have a parallel circuit, the source voltage is applied across each device. Therefore, we can use Ohm's law to calculate the current through each leg and then add the individual currents to get the total current:

$$I_1 = \frac{E}{R_1} = \frac{110}{11} = 10 \text{ amperes}$$

$$I_2 = \frac{E}{R_2} = \frac{110}{11} = 10 \text{ amperes}$$

$$I_3 = \frac{E}{R_3} = \frac{110}{55} = 2 \text{ amperes}$$

$$I_4 = \frac{E}{R_4} = \frac{110}{44} = 2.5 \text{ amperes}$$

$$I_t = I_1 + I_2 + I_3 + I_4 = 10 + 10 + 2 + 2.5 = 24.5 \text{ amperes}$$

Do you see what happened? The 15-ampere fuse that was supposed to protect the circuit would have burned out when the current exceeded 15 amperes. The 25-ampere fuse did not burn out when the safe current value was exceeded. This caused the wires inside the wall, which are designed to safely conduct only 15 amperes, to get red hot and set the house on fire.

Perhaps you think this example was overdramatized. Not at all. Fires caused by current overload happen every day, and all too frequently the cause is a "do-it-yourself" type of person who knows just enough to get himself into trouble.

A similar situation can occur in your radiology department. There are various fuses in your electrical equipment that can "blow" out. While it is a simple matter to replace a burned-out fuse with one of equal rating, that is not the proper course of action in all cases. Usually when a fuse blows, there is a reason, and the reason should be determined. There may be a short in the wiring or other defect causing the increased current in the circuit. The circuit should be checked to determine the cause of the blown fuse before the fuse is replaced. Therefore, we recommend that you have the fuse replaced by a medical equipment repairman so that he can determine the cause and make the necessary repairs.

The personnel hazard. Now, let's find out why a fuse that is capable of protecting the wiring or the equipment cannot protect you. Figure 6-3 illustrates

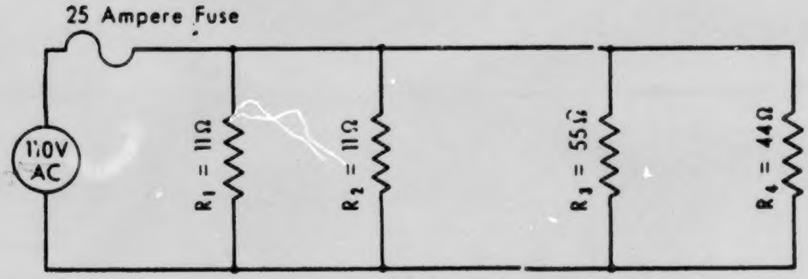


Figure 6-2. Schematic of an electrical circuit.

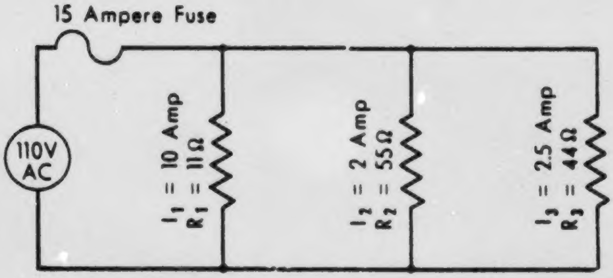


Figure 6-3. Representative parallel circuit.

a parallel circuit protected by a 15-ampere fuse. The total current in this circuit is $I_1 + I_2 + I_3 = 14.5$ amperes. As you can see, we are within the safe limit for the circuit. Figure 6-4 demonstrates the identical circuit, but with your body forming an additional parallel connection. The electrical resistance of your body, measured from hand to hand, varies from less than 5,000 to over 20,000 ohms. This resistance depends upon whether your hands are dry or wet. If you are sweaty, the resistance goes down considerably, because salt is a good conductor. For example, let's assume that your body has a resistance of 11,000 ohms, so the circuit formed would look like that in figure 6-5, with the resistance of your body represented by R_4. By adding $I_1 + I_2 + I_3 + I_4$, we find the total current to be 14.51 amperes. You can see that this is still within the safe limits of the fuse. Therefore, the fuse would not burn out, *but the 0.01 ampere of current through your body could electrocute you!*

Exercises (091):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. A fuse is designed to stop the flow of electrical current if the fuse rating is exceeded.

T F 2. Fuses protect machine operators from electrical shock.

T F 3. Fire can result from incompatability of the fuse and circuit wiring.

T F 4. A fuse protects a patient from electrical shock.

T F 5. Replacing a fuse with one of a higher rating is permitted as a temporary measure on an overloaded circuit.

T F 6. If a fuse burns out in your X-ray machine, you should replace it with one of equal rating and report the incident to your medical equipment repairman. You may continue to use the machine.

T F 7. Contact with an electrical circuit can be fatal even if the circuit is properly fused.

092. State the purpose, value, and effect of grounding an electrical appliance in given situations, and cite related safety practices.

Grounding. One of the most important, if not the most important, consideration concerning protection for both you and your patient from electrical shock is proper grounding of the equipment. How does grounding protect you and the patient? Let's see.

A typical electrical appliance. Figure 6-6,A, shows the relationships between the power wires, ground wire, and the exposed housing of an electrical machine. Notice that the housing is isolated from the wiring. The obvious reason for this is so that the machine operator will not be

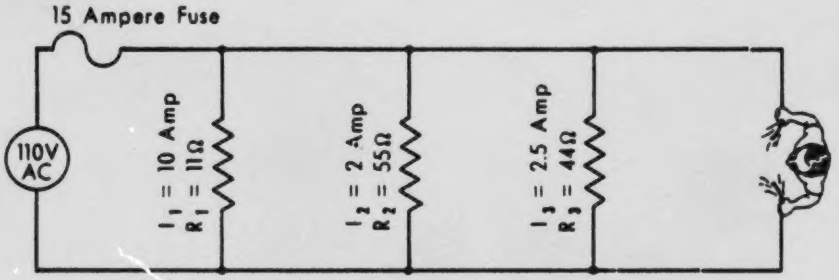


Figure 6-4. Representative parallel circuit with human body added as one element.

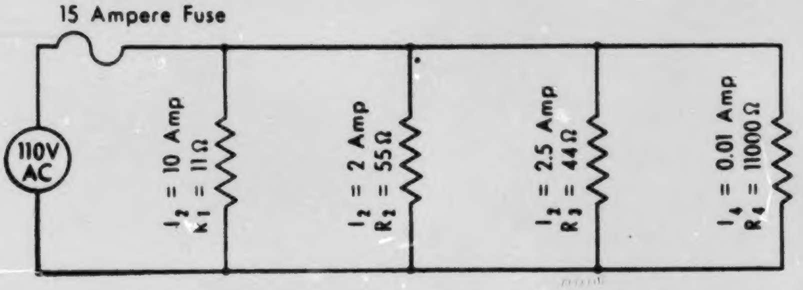


Figure 6-5. Representative parallel circuit with ohmic value of human body computed.

shocked when he touches the housing. In figure 6-6,B, we have shown an electrical connection between the hot wire and the housing. This connection could be due to worn insulation of the hot wire or to various other reasons. Now there is a possibility of current in the housing of the machine—the part that you come in contact with when you operate the machine. However, chances are you still would not be "shocked" when touching the machine because the current, which divides at the "defect," is routed through the ground wire and to "earth" ground. The reason the current flows to earth is that the ground wire offers less resistance than your body—the current takes the path of least resistance.

So far we don't have much of a problem. Even though there is a defect in the machine wiring, our ground is working properly, so the machine is relatively safe. But, suppose the machine is *not* grounded. Maybe there was no three-prong outlet available, and the ground prong of the power cord was removed so that the plug would fit into the two-prong outlet. Now there is no ground wire—no easy pathway to route the current away from the machine housing and operator (see fig. 6-6,C). However, you still probably would not receive a significant electrical shock because you still do not offer an easy path for the current. Your body is most likely at the same potential as the machine.

The next variable we will add to this hypothetical situation is for you, the operator, to come in contact with another piece of electrical equipment while touching the housing of the initial machine (see fig. 6-6,D). Now the picture has changed considerably. You have connected your body to ground potential. A circuit is formed from the housing of the initial machine, through your body, through the housing of the second machine, and out the ground wire. You definitely are going to receive an electrical shock—the severity of which depends upon the factors previously discussed. Electrocution is, of course, always possible if the conditions are right. (NOTE: If the initial appliance had been properly grounded, the current would actually "have a choice" of flowing through you to earth or through its own ground wire to earth. The easiest pathway would still be through its own ground wire because of your skin resistance.)

From the above discussion it is obvious that electrical equipment must be grounded, and it usually is—at least at the time of purchase. However, power plugs become old and defective (loose or bent); power cords and other outside wires become frayed or cracked. Some people use "cheater plugs" to adapt a three-prong plug to a two-prong outlet; and some even cut the ground prong off the power plug.

Do not use electrical equipment if defects are present as we have described. In addition, do not alter power plugs, do not use "cheater adapters," or do anything else that would interfere with the grounding of your machine.

Make a habit of checking the power plugs, power cords, or any other outside wiring about your equipment *often*. This is especially important if appliances are often moved, thereby increasing the possibility of damage. If you find any defects in a piece of equipment, do not use it. Call your medical equipment repairman.

Exercises (092):

1. According to the text, what is one of the most important safeguards to protect you and your patients from electrical shock?

2. What electrical relationship exists between the circuitry and housing of an electrical appliance in good repair? Why?

3. If an electrical connection exists between a line circuit and the housing is properly grounded, would you be shocked if you touched the housing? Explain your answer.

4. If the situation in exercise 3 above exists with the exception that there is no good ground, would you receive an electrical shock from the housing?

5. Suppose you touch the housing of an electrical appliance that is not grounded. The housing is not isolated from a live circuit. At the same time you touch a grounded X-ray machine that is not turned on. What would happen, if anything? Why?

6. List four things you should look for to help prevent an electrical shock from your piece of electrical equipment.

7. What action should you take if you find any of the discrepancies in exercise 6 above?

093. Given a simulated situation of a patient undergoing an angiocardiogram, evaluate the patient's susceptibility to electrocution.

Grounding of equipment during angiography. So far we have discussed electrical shocks from appliances through contact with the skin. There are cases in our radiology departments where the resistance of the skin is bypassed, such as during an angiogram. During such an examination, in which a catheter is inserted into the blood stream, it only takes approximately 1/1000 of the lethal skin current to produce ventricular fibrillation in the patient. During ventricular fibrillation the heart flutters with a series of uncoordinated, rapid, weak pulsations. This condition is fatal if it continues for any appreciable length of time.

If an angiogram is performed using a commercial automatic injector, there is an almost perfect electrical conductor from the injector to the patient's heart—the contrast medium in the catheter. In fact, this patient is so susceptible to

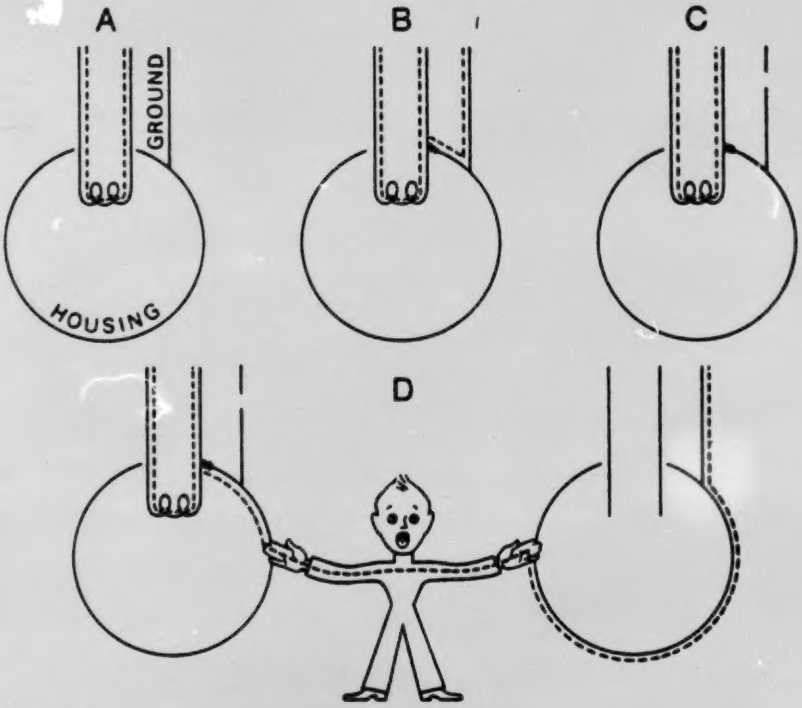


Figure 6–6. Schematics of an electrical applicance showing the relationships between live wiring, ground wire, and housing. The dotted line represents current flow.

electrocutin that we do not even need a defect in the wiring to introduce a fatal current into his blood stream. He can even be electrocuted by leakage current from an injector in good repair. Leakage current is an undesirable flow of current through or over the surface of an insulating material.

Let's look at a simulated situation and see where the danger comes from. Assume that the electrical machine we discussed in objective number 092 is an automatic injector and we are performing an angiocardiogram. The patient is naturally lying on the X-ray table and film changer, which are grounded. Already he is a prime candidate for an electrical shock because he is grounded. Let's also assume that the injector is grounded. By grounded we mean, of course, that it is properly plugged into a grounded outlet and that there are no wiring defects or other defects.

From our previous discussion in objective 092, it would seem that the patient is still safe from electrical shock—even though he is grounded. Now we will create the problem. The X-ray machine and the outlet supplying the injector are not grounded to the same ground potential. Because they are not grounded to a common ground, they may not be at the same potential. The difference in potential between the X-ray table or film changer and injector may be only a few volts. If the leakage from the injector to the contrast medium is, for example, 100 microamps, enough current can flow from the injector through the contrast medium in the catheter to the patient's heart to be fatal because the X-ray table and injector are not at the same potential. One hundred microamps is not very much current, but it is enough to cause ventricular fibrillation in this patient.

Exercises (093):

A patient who is about to have an angiocardiogram is lying on the X-ray table and film changer. An automatic injector is in position and connected to a catheter which is inserted into the patient's arm and filled with a contrast medium. Based upon the information presented in the text, answer the following questions.

1. How much relative resistance does the patient's body offer to current flow? Why?

2. What fraction of the lethal skin current can electrocute this patient?

3. Is there any danger to the patient if the injector does not contain any wiring defects? Explain.

4. What electrical conductor exists between the injector and patient? Is the conductor a good one?

5. Comment on the ground status of the patient. Does this ground increase the possibility of current flow through the patient?

6. If the injector and film changer are not at the same ground potential, is this dangerous to the patient? Explain.

094. List ways you can help create an electrically safe atmosphere for an angiographic patient.

How can you help protect your patient from electrical shock and possible electrocution? The first thing to do is to make sure that all the electrical equipment in the room is grounded to the same ground potential. This must be done by the medical equipment repairman. He may need to rewire the entire room so as to create an equipotential grounding system. Once the system is established, never ground a piece of equipment to anything else. This includes things like water pipes, which may not even be a good ground under normal conditions because nonconductive conduit is sometimes used below the ground.

Because of its importance we will repeat here what we discussed earlier. Do not alter the power plugs, wiring, or anything else affecting the equipment ground. In addition, check *all* support equipment items in which the skin resistance is bypassed. Insure that such items (examining lamps, film changers, etc.) are grounded through the use of three-prong, heavy-duty line plugs. And finally *before each examination* inspect the equipment for frayed line cords, broken plugs, deteriorated insulation, or other equipment defects.

Exercises (094):

In exercises 1 through 4 below, list four ways you can help create an electrically safe atmosphere for an angiographic patient.

1.

2.

3.

4.

095. Cite typical electrical hazards present in the darkroom, and state safety precautions that should be taken to avoid hazards.

Self-protection in the darkroom. The darkroom is a likely place for you to receive an electrical shock. One reason for this is that when you process films manually your hands are often wet, and since water is a good conductor of electricity, your natural skin resistance is lowered. Water is also occasionally present on the floor, and this increases the possibility of your being at ground potential—especially if the floor is made of cement. Another factor involved is the manual processor itself. It is mostly likely grounded through the water pipes. Let's look at a couple of darkroom situations.

Suppose that with wet hands you are transferring films from the wash tank to the dryer. The dryer has a defective ground, and the dryer housing is not isolated from the powerline (another defect). As you transfer the films, you are in contact with both the processing tank and the dryer—perhaps by way of the film hangers in both cases. The dryer switch is turned ON. You are now at ground potential, and chances are that, under these circumstances, you would receive an electrical shock because you have actually accidentally placed yourself "into" a circuit. Current would travel from the dryer housing, through a hanger to your body, through another hanger to the processor, and on to earth through the water pipes. See figure 6-7.

Let's assume instead that you are not in contact with the processing tank, but that you are standing in some water spilled on the floor. The same situation as that above occurs if the water also is in contact with the tank. See figure 6-8.

You can take several precautions to help prevent an electrical shock in the darkroom:

(1) Apply the "one-hand" rule. According to this rule, you should touch only one electrical appliance at a time to help prevent your body from being at ground potential. The processor is considered an electrical appliance (even if it contains no electrical devices, such as safelights) because it is probably grounded through the water pipes.

(2) Turn off the film dryer when loading and unloading.

(3) Turn off the power supply when changing safelights, etc.

(4) Dry your hands often and keep water off the floor. If the floor accidentally becomes wet, mop it immediately.

(5) Finally, report any electrical shocks, no matter how minor, to the medical equipment repairman so that appropriate repairs can be made.

Exercises (095):

Answer the following questions or fill in the blank spaces with one word.

1. The presence of water in the ________ increases your chances of receiving an electrical ________.
2. Why may contact with the manual processor be dangerous to you?

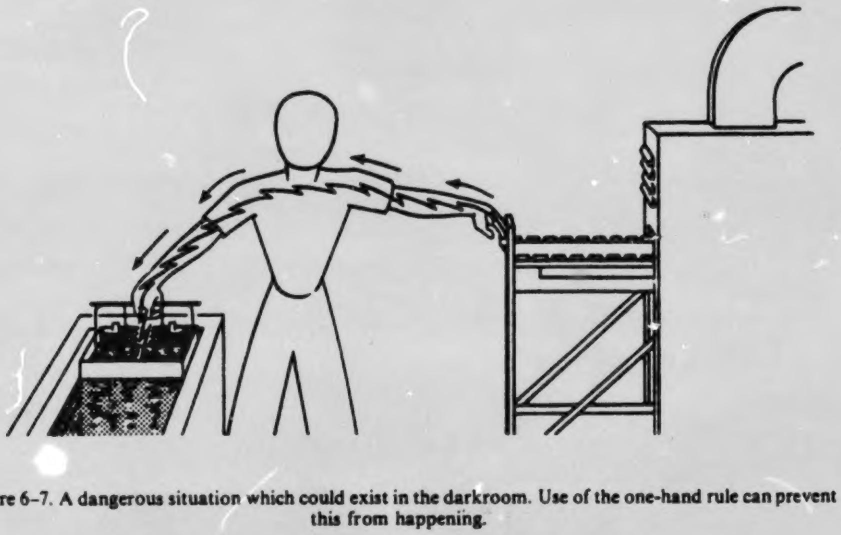


Figure 6-7. A dangerous situation which could exist in the darkroom. Use of the one-hand rule can prevent this from happening.

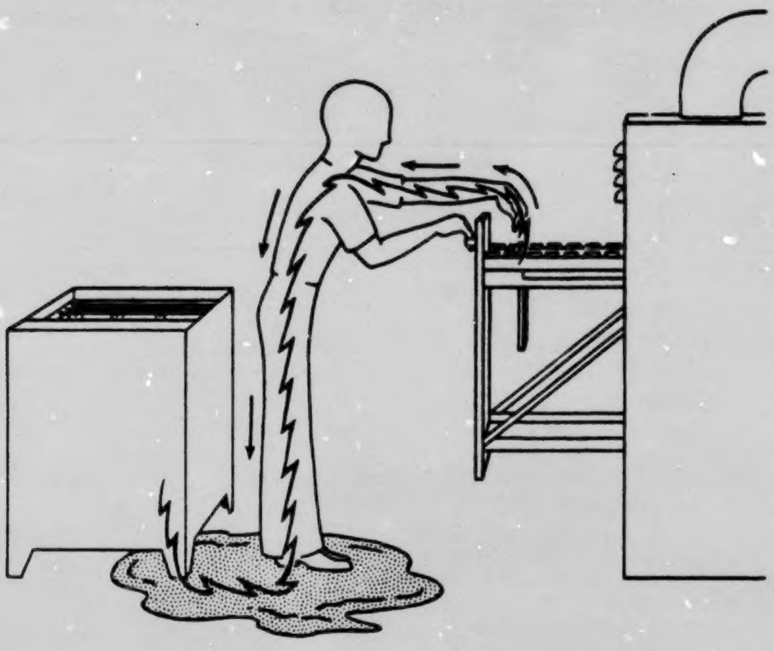


Figure 6-8. A dangerous situation which could exist in the darkroom. This can be avoided by keeping the darkroom floor dry.

3. Suppose you are transferring films from the wash tank to the dryer and are in contact with both units. Is this condition potentially dangerous? Explain.

4. To be potentially dangerous, contact between you and the processor need not be direct but can be through processing ________ or ________ on the ________.
5. What is the "one-hand" rule, and how can using the rule help protect you from electrical shock?

6. Before loading the film dryer, you should ________ it ________.
7. What action should you take in the darkroom relative to water on the floor or wet hands?

096. Given a list of statements pertaining to first aid procedures for a patient suffering from severe electrical shock, indicate which are true and which are false. If you indicate "false," explain your answer.

First Aid for Electrical-Shock Victims. When a person comes into contact with a wire carrying electricity, many things can happen. Sometimes, the victim is "frozen" to the circuit, or he may be knocked off his feet. If both voltage and current are high and the victim is in position to provide a good path to ground, the results can be fatal.

Eliminating the source. If someone does come into contact with a hot wire and is either frozen to the circuit or knocked unconscious, *turn the power OFF as quickly as possible*. If the switch is not close at hand or you cannot immediately find it, don't waste time looking. Remove the victim from the electrical source with a dry wooden pole, dry clothing, rope, parachute cord, or any other material that does not conduct electricity. If you use clothing, rope, or a cord, make it into a loop and put it over a foot, leg, or arm to drag the victim off the electrical source. Be careful not to make contact between the victim and any part of your body, or you, also, will become a victim. Severe electrical shock usually causes the victim to stop breathing, so artificial respiration must be initiated as soon as the victim is free from the electrical source.

Artificial (mouth-to-mouth) respiration. The success of mouth-to-mouth respiration often depends upon how soon it is started. Don't waste time moving the victim to an ideal location, and don't wait for mechanical equipment. To begin, place the victim on his back, use your fingers to clear his mouth and throat of any foreign matter, and make certain he hasn't swallowed his tongue. Next, tilt his head backward so that he is more or less in a "sword-swallowing" position. This will insure that his neck is not kinked and that there is a clear passage into his lungs. Then, approach the victim from his side and hold his lower jaw up by putting your fingers under his chin and your thumb on his lower teeth. Finally, use your hand to close the air passages in the victim's nose. See figure 6-9. Take a deep breath and cover his open mouth with your own until there is an airtight seal. Blow forcefully into his mouth until his chest expands. This should be done quite forcibly with adults but rather gently with children. Watch his chest as you expire. After the victim's chest rises, remove your mouth from his and allow him to exhale by himself. Repeat this action 12 to 20 times a minute. You may find that you are breathing faster than normal in order to get enough air for yourself. Actually, humans use only about 25 percent of the oxygen they inhale, so the victim is getting all he needs. Continue in a rhythmic manner and without interruption until the victim either starts breathing or is pronounced dead by a doctor.

Closed-chest heart compression. If the patient's heart has also stopped beating, you must perform closed-chest heart compression in addition to mouth-to-mouth respiration, and again it must be started immediately after the power supply has been turned off or after the patient is removed from the source of electricity.

To perform closed-chest heart compression, kneel beside the patient, place the heel of one hand on the lower end of his sternum and your other hand on top. See figure 6-10. Press downward with both hands at the rate of one compression per second. The sternum should depress 1½ or 2 inches. Lift your hands after each compression to permit the sternum to return to its normal position.

If two persons are available, one should perform mouth-to-mouth respiration, and one should perform closed-chest heart compression. If you are alone, repeat 2 good breaths for every 15 compressions of the sternum.

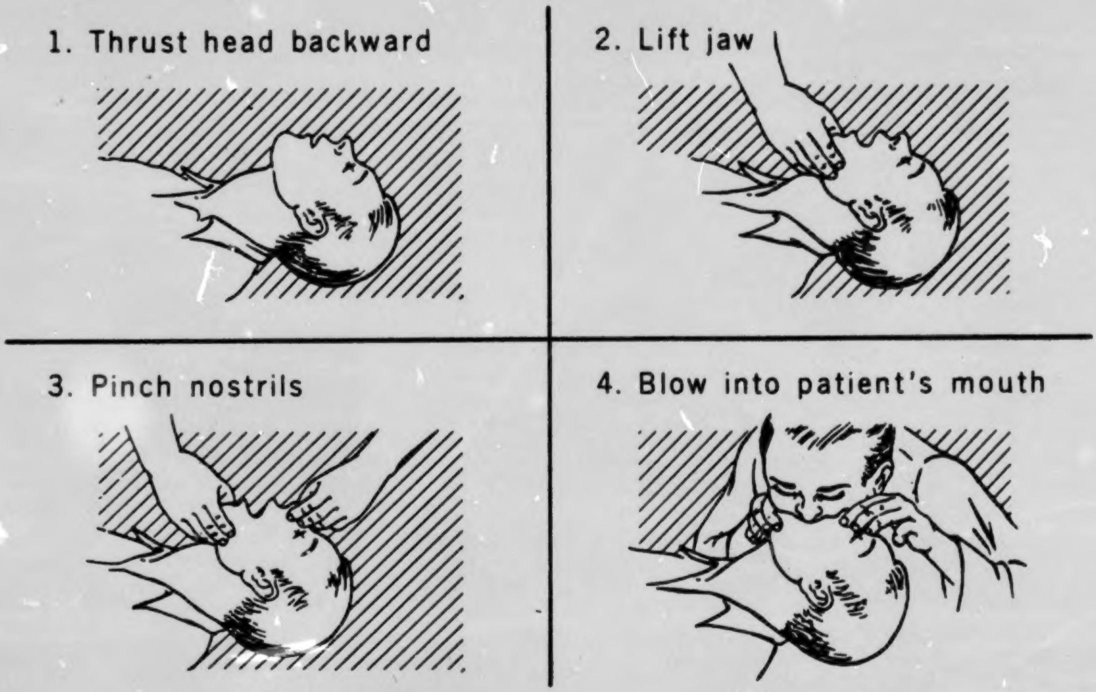
Exercises (096):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. When confronted with an unconscious electrical shock victim, the first thing you should consider is turning off the power supply.

T F 2. You can be electrocuted yourself by touching someone who is in contact with a live wire.

T F 3. You should separate an unconscious person from a live wire with the first thing you can get your hands on.



1. Thrust head backward

2. Lift jaw

3. Pinch nostrils

4. Blow into patient's mouth

Figure 6-9. Mouth-to-mouth respiration.

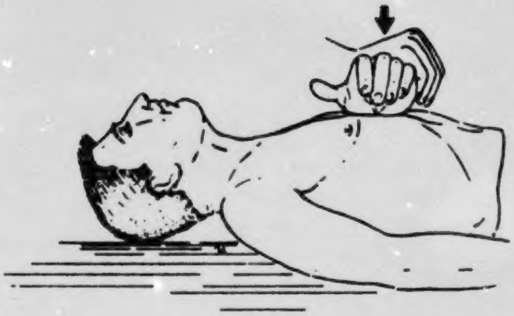


Figure 6-10. Closed-chest heart compression.

T F 4. Mouth-to-mouth respiration and closed-chest heart compression should be started immediately as soon as the victim is separated from the electrical current.

T F 5. The position of the victim's head is not important for closed-chest heart compression or mouth-to-mouth respiration.

T F 6. Your mouth should form an airtight seal over the victim's mouth during mouth-to-mouth respiration.

T F 7. When performing mouth-to-mouth respiration, you should normally force air into the patient's lungs about 15 to 20 times a minute.

T F 8. The sternum should be depressed 2 to 2½ inches during closed-chest heart compression.

T F 9. The sternum should normally be depressed 60 times a minute during closed-chest heart compression.

T F 10. If you are performing mouth-to-mouth respiration and closed-chest heart compression simultaneously on a patient, you should repeat cycles of 2 breaths followed by 15 compressions of the sternum.

6-2. Radiation Hazards and Protection for Patients

In times past, protecting our patient from excessive radiation exposure has received too little emphasis. We usually think about protecting ourselves, but some of us do not realize that our patient deserves equal consideration. As a 7 level, your responsibilities increase considerably in this area. You must not only use the appropriate safety precautions, but you must also insure that personnel under your supervision do likewise.

A good portion of this section is taken from AFM 161-38. For further information concerning radiation hazards and protection, refer to this manual.

097. Indicate the purpose, types, and use of filtration of an X-ray beam

Protective Filtration. We begin our discussion about patient protection with protective filtration. As you know, adequate filtration of the primary beam is one of the best ways to reduce the patient's exposure to radiation. Let's see how it works.

Reduction of low-energy photons. A beam of X-radiation is made up of photons with energies ranging from the kVp setting used to near zero. Many of these photons in the low-energy range are absorbed by the patient's skin and other body tissues. These "soft" photons contribute nothing whatsoever to the film exposure. All they do is increase the patient's exposure, which we obviously do not want. We cannot prevent the low-energy photons from being produced in the target of the X-ray tube, but we can remove most of them before they reach the patient. We do this by filtering the primary beam.

Types of filtration. The filters placed between the target and patient are broken down into two types, inherent and added. The first, *inherent* filtration, is that filtration provided by the tube housing. You actually have no control over this filter since it is a permanent part of the X-ray tube. However, you should be aware of the aluminum equivalency of the inherent filter for each of your X-ray machines. It is usually 0.5 mm unless the tube has a beryllium window. When such is the case, it is normally 0.3 mm. If you are not sure of the amount, check with the tube manufacturer. The second, *added* filtration, makes up the remainder of the total filtration in the X-ray beam. This type of filtration is simply what we would add to the port of the X-ray tube. Inherent filtration plus added filtration equals *total* filtration.

Minimum filtration requirements. You must have a minimum amount of total filtration in the X-ray beam. The minimum aluminum equivalency depends upon the operating kVp and is shown below:

kVp	*Minimum Total Filtration*
Below 50	0.5 mm aluminum
50 to 70	1.5 mm aluminum
Above 70	2.5 mm aluminum

For example, when you use 80 kVp, you must have a total of 2.5 mm aluminum filtration.

How filtration increases the mean energy of the beam. In figure 6-11 we have shown the energy distribution of four beams of X-radiation plotted against the intensity of the beams. Progressively more filtration is added, beginning with the top added filtration curve. Notice that the more filtration added, the fewer the number of low-energy photons, and the less the minimum photon energy of the beam. Consequently, by adding

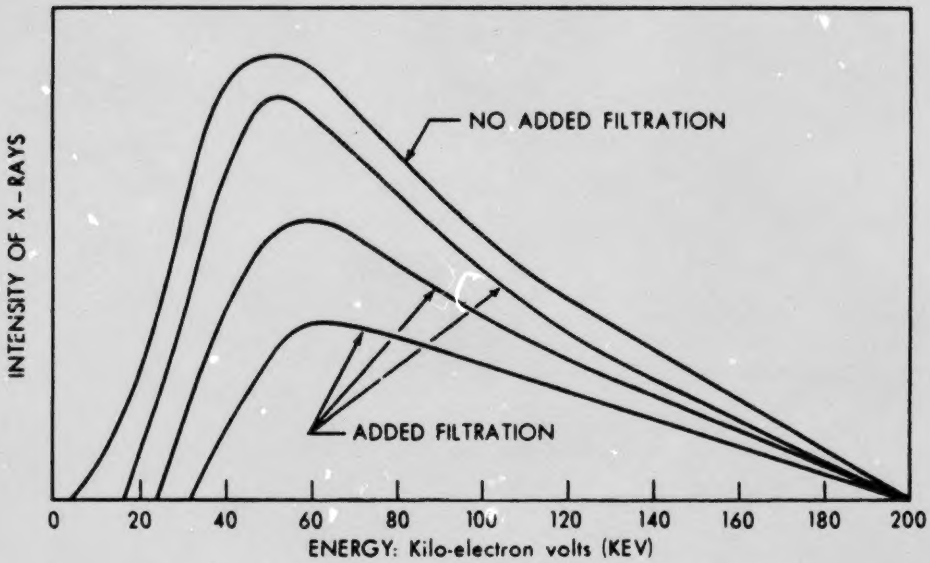


Figure 6-11. Filtration of X-ray photons.

filtration, we are increasing the mean energy of the X-ray beam.

Exercises (097):

1. What happens to the low-energy photons which do not reach the X-ray film?

2. How does filtration lower the patient's exposure?

3. What is inherent filtration? How much is normally provided in an X-ray tube?

4. If an X-ray tube has 0.3 mm aluminum equivalency of inherent filtration, how many millimeters of aluminum should be added to operate the tube at 26 kVp?

5. How much total filtration should be in the X-ray beam if 65 kVp is used?

6. If the inherent filtration of an X-ray tube is 0.5 mm, how many millimeters of aluminum should be added to operate the tube at 120 kVp?

7. How does filtration of the beam of X-ray photons increase the beam's mean energy?

098. State three ways in which high kVp techniques reduce patient exposure.

High kVp Techniques. We have just discussed how filtration reduces patient exposure by increasing the mean energy of the primary beam. It is not practical, however, to increase the filtration very much beyond the minimum requirements to further reduce patient exposure. The reason for this is that filters work well up to a certain point, but then reduction in patient exposure with more filtration diminishes rapidly.

There is another way to reduce patient exposure by increasing the mean energy of the beam —simply by using high kVp techniques. By high kVp we do not mean 100 kVp or 150 kVp. We mean the highest kVp that produces a radiograph which satisfies your radiologist. As you know, the higher the kVp, the longer the scale of contrast; but your initial concern is providing radiographic contrast consistent with your radiologist's desires. So whatever kVp range you use, remember it must first satisfy the radiologist.

Let's look at a typical examination of the knee. If you presently use 60 to 70 kVp, you may very well be able to increase the kVp to 80 to 90 and still maintain satisfactory contrast. Eighty to 90 kVp is not considered high, but it is higher than you previously had used, and you have taken a positive step in reducing exposure to your patient.

Aside from reducing patient exposure by increasing the mean energy of the beam, high kVp works in two other ways to reduce patient exposure: (1) it permits shorter exposure times—which helps prevent repeat examinations due to part motion and (2) it also provides more exposure latitude, which also helps to prevent repeat examinations due to incorrect exposure factors. Of course, any action that reduces the repeat radiographs also helps to keep patient exposure to a minimum.

Exercises (098):

In the exercises below, write down three ways high kVp techniques reduce patient exposure.

1.

2.

3.

099. List two ways that proper collimation reduces patient exposure, and indicate the basic procedure for checking the collimation of a radiograph.

Collimation. One of the best ways to keep patient exposure to a minimum is by restricting the primary beam to the smallest area consistent with the clinical requirements. Exposure of the patient to radiation in areas beyond the part under study is in most cases inexcusable, since collimators have a field-size scale as well as a lighted X-ray field. There is no excuse to open the collimator wide open for a radiograph. There is likewise no excuse to open the collimator beyond the size of the film. In fact, in most cases you should use an X-ray field smaller than the film.

Checking for collimation is an important part of your quality control duties. For *most* radiographs you should see the outer limits of the X-ray field on the film. We emphasize "for most radiographs" because at times, due to the size of the patient, for example, it is necessary to use an X-ray field to cover the entire film. This is the exception, however, and not the rule.

It is difficult to say, for example, that all radiographs should have a 1-inch unexposed border around the sides. Film size, patient size, and the part being radiographed are some factors that should be taken into consideration. The important issue is that you should see the outer limits of the field. If you do not see a border around the film, you aren't sure whether the X-ray field extends 1 inch or 10 inches beyond the film.

In addition to increasing patient exposure, a large X-ray field increases the scatter radiation to the film, thereby increasing film fog. As you know, excessive film fog on a radiograph can cause it to be repeated.

Exercises (099):

1. Give two ways that proper collimation reduces patient exposure.

2. As a general rule, what should you look for on a radiograph to insure proper collimation?

3. If you do not see any indications of collimation on a radiograph, what can you assume about the size of the X-ray field?

4. What size unexposed border should you see on the edges of a radiograph?

100. Name several examinations in which gonadal shielding can be used, and specify two precautions to take when using the shielding.

Gonadal Shielding. To prevent needless exposure of the patient's gonads, you should cover them with pieces of lead-rubber shielding material. For example, gonadal shielding can be used for hip examinations if you are careful with the placement of the shield. You can also shield the gonads of femur and lumbar spine examinations of male and female patients and abdomen, intravenous pyelogram, sacrum, and coccyx studies of male patients.

The most important consideration when using gonadal shielding is to make sure the shield is not superimposed over the part under study. In addition, do not use gonadal shielding as a substitute for adequate beam collimation. Use the shield in *addition* to collimation.

Exercises (100):

1. Name three examinations where gonadal shielding can be used on male and female patients.

2. Name four examinations where gonadal shielding can be used on male patients only.

3. What two precautions should be considered when using gonadal shielding?

101. Show the effect and use of high-speed screens and films to reduce patient exposure.

High-Speed Screens and Films. Using high-speed intensifying screens and X-ray films can also reduce patient exposure to radiation by lowering the exposure necessary to produce the radiograph. Keep in mind that there is a loss of detail when high-speed films and screens are used. So this is a decision that should be made by your radiologist. If he is willing to accept the detail loss to reduce patient exposure, then by all means use high-speed films and screens.

At times it may be advantageous to use high-speed screens for most examinations and to use the medium or slow-speed for radiographs of parts requiring maximum detail such as the mastoids. In cases such as this, make sure that the cassettes are plainly identified so that, for example, high-speed exposure factors are not used with slow-speed screens.

Exercises (101):

1. Why is patient exposure reduced if high-speed intensifying screens and films are used?

2. What must be sacrificed if you use high-speed intensifying screens and films?

3. How can you maintain good screen detail for some examinations and keep patient exposure to a minimum for others?

102. Given characteristic curves of three identical X-ray films, relate developing time to patient exposure.

Film Processing. A common cause of excessive patient exposure is improper film development. To illustrate how film development affects patient exposure, we have shown, in figure 6-12, the characteristic curves of three identical films processed under different conditions. Film A was developed as recommended by the film manufacturer for a period of 5 minutes at 68° F. Film B was developed under the same conditions but for only 3 minutes. Film C also was developed under the same conditions but for only 1½ minutes. Now, let's analyze the results of figure 6-12. At the bottom of the curve, you will notice that the log relative exposure is in increments of 0.3 and, also, that each increment of 0.3 is equivalent to doubling the mAs. Next, assume that your radiologist wants films taken at a certain kilovoltage with a maximum density of 2.0. To reach this density, film A would need 11 mAs, film B would require 40 mAs, and film C approximately 270 mAs. Can you now see why proper developing becomes so very important in reducing radiation dosage to the patient? The film developed at 1½ minutes requires 24 times the exposure of film A.

Exercises (102):

1. According to figure 6-12, what developing time requires the most exposure to produce a specific density?

2. According to figure 6-12, what developing time requires the greatest patient exposure to produce a particular radiograph?

3. What can you conclude from the discussion about developing time vs. patient exposure?

4. What developing time should you use for all your radiographs?

6-3. Radiation Hazards and Protection for Technicians

Good working habits, commonsense, and proper respect for ionizing radiation are very important in radiation protection. With present day knowledge and the vast amount of protective resources at your disposal, there is absolutely no reason for you to even closely approach the maximum permissible dose. If proper precautionary measures are practiced daily, the risk involved in being an X-ray

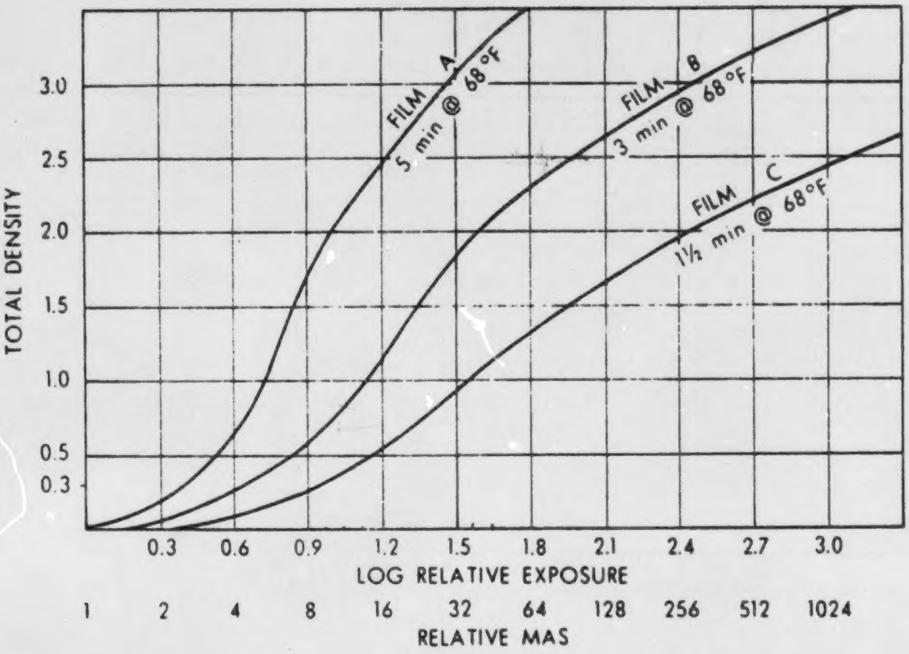


Figure 6-12. Characteristic curves of several identical films.

technologist is very small, when compared to other risks, such as driving a car and crossing the street. The steps necessary to keep your exposure at a minimum can be divided into two categories: (1) those that protect you from the primary beam and (2) those that protect you from scatter radiation.

103. List four rules to follow to protect yourself from exposure to radiation.

Protection from the Primary Beam. Protecting yourself from primary radiation is very simple: do not expose any part of your body to the primary beam. This means that during exposure you should never hold a patient or cassette, or in any other way subject yourself to primary radiation. In addition, you should not allow another technician to perform these tasks. If assistance is needed to obtain a radiograph on uncooperative patients, use someone who is not occupationally exposed to ionizing radiation.

Protection from Scatter Radiation. Although the intensity of scatter radiation is less than primary radiation (for a given technique), the radiation hazard to the technician is perhaps greater with scatter. The reason for this is that scatter radiation can reach virtually all parts of the exposure room while the primary beam is restricted to an area that is much smaller by comparison. Therefore, while it is a simple matter to remain clear of the primary beam, it is somewhat more difficult to elude scatter radiation. Following are some general rules to adhere to.

Standing behind a protective barrier. Always remain behind a protective barrier when making an exposure. Control booths are designed so that the technologist will not be exposed to any radiation that has scattered only once. In other words, the radiation must scatter at least twice before it reaches you. Use the lead impregnated glass window to observe the patient. Do not defeat the purpose of the control booth by leaning out from behind the barrier to make the exposure.

Using distance for protection. Distance is an effective means to reduce exposure. Since radiation intensity decreases as the distance from the source increases, exposure can be reduced by staying as far from the source as possible. This rule is particularly important to remember when taking portable radiographs, where protective barriers are usually not available.

Protection during fluoroscopy. During fluoroscopy be sure to wear a protective apron. When you are not needed to assist the radiologist, remain in the control booth.

Exercises (103):

In exercises 1 through 4 below, list four rules to follow to protect yourself from exposure to radiation.

1.

2.

3.

4.

6-4. The Personnel Dosimeter

The purpose of the USAF personnel dosimeter is to measure and record the accumulative dose of ionizing radiation to radiation workers like yourself. In addition to recording the exposure received, the dosimeter can prevent excessive exposures by determining that a radiation "leak" or other hazard exists, before the hazard becomes dangerous. Let's begin our discussion with your responsibilities concerning the dosimeter. (NOTE: This section is based on AFR 161-28, *Personnel Dosimetry Program and the USAF Master Radiation Exposure Registry*. Refer to this regulation for additional information concerning the dosimetry program.)

104. Identify your responsibilities pertaining to the USAF Personnel Dosimetry Program.

Supervisor Responsibilities. Your responsibilities concerning this program are fairly simple—but important ones. If you are acting in the capacity of a supervisor, you must see to it that each person under your supervision is thoroughly indoctrinated in the proper use of the dosimeter. When a new technician is assigned to your department, go over the procedures with him. Do not assume that he already knows how and when to wear the dosimeter just because he has been in radiology for some time.

Technician Responsibilities. If you are not acting as a supervisor, you are responsible for the proper use of the dosimeter issued to you. The best reason for you to use the dosimeter properly is that it might prevent a significant dose of radiation to you. In other words, you are the one who benefits from the dosimetry program, so act accordingly.

Exercises (104):

Explain your responsibilities, both as a technician and as a supervisor, pertaining to the dosimetry program.

1. Supervisor responsibilities.

2. Technician responsibilities.

105. Given a list of statements pertaining to wearing and handling of the dosimeter, indicate which are true and which are false. If you indicate "false," explain your answer.

Wearing and Handling the Dosimeter. There are certain problems that we will discuss that involve both the wearing and the handling of dosimeters. Our discussion will include dosimeter choice, when and where they are to be worn, and storage areas.

Chest dosimeter. The regular chest dosimeter (film badge) is worn below the shoulders and above the waist on the outside of the clothing. If you wear a lead apron, wear the dosimeter beneath the apron but still outside the clothing. The film must face outward from the body with the clip on the holder facing toward the body. This dosimeter, which we will call the chest dosimeter, is worn at all times during radiography, therapy, or fluoroscopy to measure whole-body exposure.

Flouroscopic dosimeter. In addition to the chest dosimeter, you must wear an additional dosimeter during flurorscopy. Wear this fluoroscopic dosimeter only on your front collar outside the protective apron. Its purpose is to assess the radiation exposure to the head and to the lens of the eye.

Localized exposure dosimeters. Additional dosimeters can be worn in certain situations, as during fluoroscopy, to assess localized exposures, such as to the neck or forearm. When wearing these additional dosimeters, be sure to wear the other required dosimeters.

Keep in mind that each dosimeter has a specific purpose. Consequently, during a specific reporting period, you shouldn't interchange the dosimeters. For example, the chest dosimeter should not be worn on other areas of the body. Also, if a dosimeter is used to record exposure to a localized area, it must not be worn at any other body site unless the dosimeter film is changed.

Where to wear the dosimeters. You must clip on the dosimeter(s) before entering the working area and remove it when leaving. The working area, as far as radiology departments are concerned, is the entire department. This means that you can wear the dosimeters anywhere inside the department. This also means that you cannot wear the dosimeter outside the department. Except, of course, you can wear the dosimeter outside the department when performing portable radiographs.

Dosimeter storage area. While dosimeters are not being worn, they must be stored in a storage area designated by the commander of the facility. The storage area should be near to, but outside, the radiation area. Radiation area in this case refers to the exposure—therapy rooms. For convenience, it is advisable to locate the storage area near the entrance of the department, thereby encouraging technicians to deposit or remove the dosimeter as they leave or enter the department.

Identifying the dosimeters. To insure that each technician wears only his own dosimeter, it should contain some individual identification, with the corresponding identification placed at a given location on a dosimeter storage rack. Do not permanently inscribe the identification on the dosimeter. Use embossing tape or other similar means to identify the dosimeter. You can identify the dosimeter on the front surface as long as the small window is not covered. To cover the window may cause false (lower than normal) readings.

Exercises (105):

Indicate whether the following statements pertaining to wearing and handling the dosimeter are true or false. If you indicate "false," explain your answer.

T F 1. The chest dosimeter can be worn attached to a shirt pocket.

T F 2. The chest dosimeter can be worn attached to the belt.

T F 3. The chest dosimeter is not worn during fluoroscopy.

T F 4. At least two dosimeters must be worn during fluoroscopy.

T F 5. During fluoroscopy, one dosimeter is worn beneath the apron, and one is worn outside the apron.

T F 6. The fluoroscopic dosimeter assesses whole-body exposure.

T F 7. When wearing a localized exposure dosimeter, you do not have to wear the chest dosimeter.

T F 8. The fluoroscopic dosimeter can be used to assess exposure to the hands.

T F 9. You cannot wear a dosimeter outside the radiology department.

T F 10. Dosimeters can be stored in an exposure room.

T F 11. Individual identificatin of dosimeters should be made on the dosimeter and on the storage rack.

T F 12. Identification should not be placed on the front of the dosimeter.

T F 13. At least three dosimeters must be worn to measure whole-body exposure.

ANSWERS TO EXERCISES

CHAPTER 1

Reference:

001 - 1. The flow of electrons through a conductor.
001 - 2. Difference between electrostatic charges, difference in potential, and resistance.

002 - 1. An insulator is a poor conductor of electricity, a conductor is a good conductor of electricity, and a semiconductor is neither a good conductor nor a good insulator.
002 - 2. Conductor.
002 - 3. Semiconductor.
002 - 4. Insulator.
002 - 5. Semiconductor.
002 - 6. Conductor.
002 - 7. Conductor.

003 - 1. T.
003 - 2. T.
003 - 3. F. Under the conditions described, 0.33 ampere of current is flowing.
003 - 4. F. The symbol I refers to the intensity of current, or amperes.
003 - 5. T.
003 - 6. T.
003 - 7. F. They are the same.
003 - 8. F. Voltage can exist between two positive charges if one is more positive than the other.
003 - 9. F. Current flows from negative to positive.
003 - 10. T.

004 - 1. The opposition to current flow.
004 - 2. Ohm.
004 - 3. That amount which allows exactly 1 ampere of current to flow when 1 volt is applied across the resistance.
004 - 4. $R = 4\ \Omega$.

005 - 1. No.
005 - 2. Less; more.
005 - 3. 2 Ω.
005 - 4. Resistance depends upon the number of electron collisions, and the length of a conductor influences the number of collisions.
005 - 5. 0.5 Ω.
005 - 6. Yes; increase.
005 - 7. Temperature

006 - 1. 22 Ω.
006 - 2. 110 volts.
006 - 3. 3 amperes.

007 - 1. Crossed over wires.
007 - 2. Connected wires.
007 - 3. Battery.
007 - 4. Lamp.
007 - 5. Fixed resistor.
007 - 6. Voltmeter.
007 - 7. Switch.
007 - 8. Ground.
007 - 9. Ammeter.
007 - 10. Fuse.
007 - 11. Variable resistor.

008 - 1. 0.5 A; 0.5 A; 0.5 A.
008 - 2. 24 Ω.
008 - 3. 6 V; 2 V; 4 V.

009 - 1. 12 V; 12 V.
009 - 2. 4 A; 6 A; 12 A; 2 A.
009 - 3. 24 A.
009 - 4. 0.5 Ω.

010 - 1. 7.8 Ω.

Explanation:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_t} = \frac{1}{2} + \frac{1}{2} + \frac{1}{4}$$

$$\frac{1}{R_t} = \frac{5}{4}$$

$$5R_t = 4$$

$R_t = 0.8\ \Omega$ = equivalent resistance of the three parallel resistances

$$7\ \Omega + 0.8\ \Omega = 7.8\ \Omega.$$

011 - 1. A force that attracts iron, steel, or other magnetic substances.
011 - 2. Around and inside the magnet.
011 - 3. Outside the magnet: from the north pole to the south pole. Inside the magnet: from the south pole to the north pole.
011 - 4. Concentration of lines of force.
011 - 5. Like poles repel each other. Unlike poles attract each other.

012 - 1. Magnetic substances are strongly affected by a magnetic field; nonmagnetic substances are not noticeably affected.
012 - 2. Magnetic: iron and steel. Nonmagnetic: wood, copper, and glass.
012 - 3. T.
012 - 4. T.
012 - 5. T.

013 - 1. Current flow must be present through the conductor.
013 - 2. No. Form the wire into one or more loops.
013 - 3. At each end of the coil.
013 - 4. The direction of current flow.
013 - 5. Place the left hand around the conductor with the thumb pointing in the direction of current flow. Lines of force travel in the same direction as the fingers.

014 - 1. The number of coil turns per inch. The higher the number of turns, the stronger the field.
014 - 2. Current through the conductor. The higher the current, the stronger the field.
014 - 3. Iron core. The core itself becomes magnetized, and its strength is added to that of the coil; and the core strengthens the field because lines of force concentrate themselves in the core.

015 - 1. T.
015 - 2. T.

016 - 1. Fixed.
016 - 2. Relay.
016 - 3. Magnetic.
016 - 4. Electromagnet; privoting.
016 - 5. Opened; spring-.

017 - 1. Electromagnetic effect.
017 - 2. Permanent magnet, moving-coil movement.
017 - 3. Two—permanent and electromagnet.
017 - 4. When current is introduced into the coil, the poles of the electromagnet attempt to repel the same poles of the permanent magnet.

018 - 1. a, b.
018 - 2. a.
018 - 3. b.

019 - 1. 1/120 second.
019 - 2. No. When the sine wave reaches zero value, there is no current flow.
019 - 3. 1/240 second.
019 - 4. Two.
019 - 5. One.
019 - 6. The number of cycles per second.

020 - 1. The process of producing an EMF from the relative motion between a conductor and a magnetic field.
020 - 2. A conductor, a magnetic field, and relative motion.
020 - 3. The more lines of force that are cut per unit time, the higher the induced EMF.
020 - 4. The more conductors, or number of turns in a coil, the higher the induced EMF.

021 - 1. T.
021 - 2. T.
021 - 3. T.

022 - 1. The process of transferring electrical energy from one circuit to another by electromagnetic induction.
022 - 2. 11 volts, 50 amperes.
022 - 3. 660 volts, 1 ampere.

023 - 1. To vary the kilovoltage output of the high tension transformer and to regulate the supply voltages for operating the X-ray generator.
023 - 2. Adjusting the autotransformer line voltage compensator control so that a predetermined reading is obtained on the line voltage compensator meter.
023 - 3. The exposure will be lighter or darker than normal because the voltage across the X-ray tube is not consistent with the setting on the control panel.
023 - 4. kVp major and minor selectors, which are located in the secondary of the high tension transformer.

024 - 1. a, b.
024 - 2. a.
024 - 3. c, d.
024 - 4. a.
024 - 5. c.
024 - 6. b.
024 - 7. a.
024 - 8. d.

025 - 1. Voltage ripple is the difference between the minimum and maximum voltage of a single wave form pulse.
025 - 2. The average kinetic energy of the electrons across the X-ray tube.
025 - 3. Three-phase, twelve-pulse.
025 - 4. Slightly higher with twelve-pulse.
025 - 5. Considerably higher with six-pulse.

026 - 1. The higher the average electron energy, the higher the average photon energy.
026 - 2. Average photon energy is higher with three-phase.
026 - 3. Three-phase.

027 - 1 The intensity is greater with three-phase.
027 - 2. With single-phase there is (1) a period of time when nonimage forming radiation is produced and (2) a period of time when no radiation is produced. With three-phase, image-forming radiation is continuously produced.

028 - 1. 106 kVp.
108 - 2. It will maintain approximately the same scale of contrast and keep the patient's absorbed dose to a minimum.

029 - 1. Three-phase. There are no "hot spots" on the target, resulting in a more even thermal load.
029 - 2. Approximately equal.
029 - 3. Greater with single-phase.

030 - 1. To aim or focus the electrons to a specific area on the anode.
030 - 2. Filament.
030 - 3. Length.
030 - 4. Large.
030 - 5. The state of the filament when it is heated to the required emission temperature.
030 - 6. Use the STAND-BY button only when necessary and then only for a short period of time.

031 - 1. It is positively charged with respect to the cathode.
031 - 2. Target.
031 - 3. It has a high melting point and high atomic number.
031 - 4. Affects the heat-loading capacity of the tube.
031 - 5. Size of the actual focal spot and angle of the target.
031 - 6. A design characteristic of an X-ray tube that produces a relatively large actual and relative small effective focal spot.
031 - 7. The smaller the target angle, the smaller the X-ray field; consequently, the field covers a smaller X-ray film at a specific FFD.
031 - 8. 12°.
031 - 9. Biased focal spot. It eliminates the concentration of electrons on the outer sides of the target, thus preventing a "double image" on the radiograph.

032 - 1. Shorter exposures. The exposure can be synchronized to a particular portion of the sine wave.
032 - 2. Less radiation to the patient. (1) Exposures can be short enough so that portions of the wave that produce low energy are not used, and (2) X-ray exposures can be synchronized with cine camera shutters so that radiation is produced only when the shutter is open.

033 - 1. 1,600 H.U.
033 - 2. 1,498 H.U.

034 - 1. 200.
034 - 2. 50.
034 - 3. 1/20 sec.
034 - 4. a. Yes.
b. No.
c. No.
034 - 5. 110.
024 - 6. 125.
034 - 7. 0.05 sec.
034 - 8. a. No.
b. Yes.
c. No.

035 - 1. Yes.
035 - 2. No.
035 - 3. No.

036 - 1. None. Explanation: 140,000 H.U. + 140,000 H.U. = 280,000 H.U. Capacity is 300,000 H.U.
036 - 2. Approximately 3½ minutes.
036 - 3. Indefinitely.
036 - 4. Eight minutes.
036 - 5. Four.

CHAPTER 2

037 - 1. T.
037 - 2. F. Some X-ray photons must penetrate the part and reach the film for good visualization of a part.
037 - 3. T.
037 - 4. T.
037 - 5. T.
037 - 6. F. The average energy depends upon the energies of the photons.
037 - 7. T.
037 - 8. F. An increase in kVp increases the maximum energy.
037 - 9. T.

038 - 1. The characteristic of the primary beam that affects radiographic density. It is a measure of the number of photons per unit area in combination with the mean energy of the photons.
038 - 2. a, c.
038 - 3. d.
038 - 4. d.
038 - 5. a, c.
038 - 6. c.
038 - 7. a.
038 - 8. a, c, d.
038 - 9. a, c.

039 - 1. The intensity of radiation in the primary beam is inversely proportional to the square of the distance from the target.
039 - 2. 800. 50.
039 - 3. No. Intensity as affected by the inverse square law has nothing to do with the number of photons emitted from the target. It is concerned with the number of photons per unit area.
039 - 4. There is no connection between the two.

040 - 1. Longitudinal; anode heel effect.
040 - 2. Farthest.
040 - 3. Anode.
040 - 4. Increases; decrease.
040 - 5. 32°.
040 - 6. Cathode.
040 - 7. Absorption; target material.

041 - 1. Room #1.
041 - 2. Since the difference between the sizes of the upper and lower portions of the thoracic spine is greater than normal, you would need the tube with the greatest variation in intensity to balance out the density on the radiograph. The 12° provides the greatest variation.
041 - 3. Room #2.
041 - 4. With his head toward the anode side of the tube.
041 - 5. Any of the rooms could be selected.
041 - 6. For spot-films of the gallbaldder you would only use the small central portion of the X-rays. field. The variation in intensity for such a small area is negligible.
041 - 7. With the ankle toward the anode.
041 - 8. The portable. At a 30-inch FFD, the beam intensity varies more.

042 - 1. F. A small focal spot gives better detail.
042 - 2. F. A large focal spot produces more penumbra.
042 - 3. F. The more penumbra, the worse the detail.
042 - 4. F. Penumbra is greatest on the cathode side.
042 - 5. F. Radiographs do have better detail on the anode side, but the reason has nothing to do with distance from the target. That portion is projected by a "smaller" focal spot.

043 - 1. Room #1. Room #2.
043 - 2. The 1.5 mm in room #1 because it is the smallest of the four able to withstand the exposure.
043 - 3. Your initial thought should be on the smallest focal spot you have available (0.2 mm in exposure room #1) since detail is most important on this examination. If the exposure factors do not exceed the rating of the 0.2-mm focal spot, it should be used. If you cannot safely use the 0.2 mm, check the exposure against the next largest focal spot (0.5 mm in room #2) and so on until you find the smallest focal spot that can withstand the exposure. Remember, even though detail is important, not to exceed the maximum rating of the tube rating chart.

044 - 1. The right lateral. The part-film distance for the right side would be less than for the right side; therefore, there would be less magnification and better detail of the right parietal bone.
044 - 2. Radiograph B.
044 - 3. The posterior ribs of radiograph A.
044 - 4. Radiograph B.
044 - 5. You could decrease the FFD. A shorter FFD increases magnification and therefore decreases detail.
044 - 6. The right lateral. It places the right lower lobe closer to the film, thereby providing better detail of that area.
044 - 7. An increase in FFD. Increased FFD increases detail.

045 - 1. Keep it to a minimum, but use it when necessary.
045 - 2. Yes. At times distortion is necessary to project a part clear of superimposed structures.
045 - 3. To the part, perpendicularly to the plane of the part and the plane of the film.
045 - 4. Yes.
045 - 5. The plane of the part must be parallel with the plane of the film.

CHAPTER 3

046 - 1. F. A beam-restricting device reduces the size of the primary beam.
046 - 2. T.
046 - 3. T.
046 - 4. T.
046 - 5. F. You can reduce scatter by using a smaller X-ray field.
046 - 6. T.
046 - 7. T.

047 - 1. Set the scale to a specific field size at a specific FFD. Make an exposure. Measure the X-ray field and compare it to the scale setting.
047 - 2. Yes.
047 - 3. No.
047 - 4. No.
047 - 5. No.

048 - 1. Place the 90° angles of the four wires so that they correspond to the four corners of the lighted field.
048 - 2. Two.
048 - 3. To insure visualization of the wire pieces.
048 - 4. By placing an orientation marker on the radiograph.
048 - 5. Measure the sides of the lighted field and the sides of the X-ray field.
048 - 6. No.
048 - 7. Yes.
048 - 8. Yes.
048 - 9. No.

049 - 1. By absorbing most of the scattered radiation before it reaches the film.
049 - 2. No, but it absorbs the greatest portion.
049 - 3. No, a small portion is absorbed.
049 - 4. Because of the angles at which they approach the grid. Primary radiation approaches at angles the same as the lead strips, while scattered radiation approaches the strips at acute angles.
049 - 5. a.
049 - 6. b.
049 - 7. a.
049 - 8. a.
049 - 9. b.
049 - 10. b.
049 - 11. c.

050 - 1. a.
050 - 2. a, b.
050 - 3. a.
050 - 4. b.
050 - 5. b.
050 - 6. a.
050 - 7. a.
050 - 8. b.

051 - 1. The radiograph made with the 8:1, 100-line grid, because the strips are thinner and are not as high.
051 - 2. The more lines per inch, the lower the contrast; less scattered radiation is absorbed because there is less lead in the grid.

052 - 1. a.
052 - 2. a, b.
052 - 3. a.
052 - 4. b.
052 - 5. b.
052 - 6. a, b.

053 - 1. T.
053 - 2. T.
053 - 3. F. A recipromatic Bucky permits the shortest exposure time.
053 - 4. F. A moving Bucky must be manually cocked before each exposure.
053 - 5. F. The timer is manually set on a moving Bucky.
053 - 6. T.
053 - 7. T.
053 - 8. T.
053 - 9. F. A 15-percent increase is necessary when changing from stationary grid to Bucky technique.

054 - 1. Grid B. A higher ratio grid absorbs more scatter. The effective ratio of grid B is 10:1.
054 - 2. Grid B. A higher ratio absorbs more scatter.
054 - 3. Grid A. A greater proportion of the scatter is absorbed at 70 kVp because scattered radiation at 120 kVp is more likely to penetrate the lead strips and reach the film.
054 - 4. Grid A. Less scatter is absorbed because there is less lead in the grid.

055 - 1. It causes an even loss of density over the film.
055 - 2. The radiograph made with the 5:1 grid.
055 - 3. A grid with a long grid radius reduces density less than does a grid with a short radius.
055 - 4. One inch.
055 - 5. None.
055 - 6. The 5:1, 72-inch, focused grid.

056 - 1. There is a loss of density on the lateral margins of the film.
056 - 2. The radiograph using the 32-inch focus-grid distance because the loss of primary radiation and density is greater with "near" decentering than with "far" decentering.
056 - 3. A high-ratio grid causes greater loss of primary radiation than does a low ratio grid.
056 - 4. Make experimental exposures and note the focus-grid distances where significant loss of primary radiation (density) occurs.

057 - 1. Two conditions could cause the variation. There could be far-distance decentering with lateral decentering over side B or near-distance decentering with lateral decentering over side A.
057 - 2. Two conditions could cause the variation. There could be far-distance decentering with lateral decentering over side A or near-distance decentering with lateral decentering over side B.

058 - 1. a. 8°.
  b. 6°.
  c. 3°.
  d. 1°.
058 - 2. An even loss of density over the film.

CHAPTER 4

059 - 1. c.
059 - 2. a.
059 - 3. f.
059 - 4. b.
059 - 5. d.

060 - 1. b.
060 - 2. a.
060 - 3. a.
060 - 4. c.
060 - 5. b.
060 - 6. a.
060 - 7. a.
060 - 8. b.
060 - 9. b.

061 - 1. The ratio of light transmitted through a film to the incident light.
061 - 2. a. 1.
  b. 2.
  c. 3.

062 - 1. 60 mAs.
062 - 2. 8.75 mAs.

063 - 1. A.
063 - 2. A, B.
063 - 3. C.
063 - 4. A.
063 - 5. C.
060 - 6. A.
063 - 7. C.
063 - 8. A.

064 - 1. To reduce the exposure necessary to produce the desired radiographic density.
064 - 2. a. Base—support.
  b. Reflecting material—reflects light photons, emitted away from the film, back toward the film.
  c. Phosphor—emits visible light when exposed to X-rays.
  d. Protective coating—prevents static, protects the phosphor, and permits cleaning.

065 - 1. Screen films are especially sensitive to blue-violet light, which is emitted by intensifying screens.
065 - 2. Fast. Slow.
065 - 3. Slow. Fast.
065 - 4. The larger the size of the crystals and the thicker the layer, the less the detail.
065 - 5. Large crystals and a thick layer causes more light diffusion, which in turn causes overlapping of the areas under study.

066 - 1. F. The test is made to determine if there is a loss of detail.
066 - 2. F. It results in more light diffusion.
066 - 3. T.
066 - 4. F. Unsharp areas indicate poor screen-film contact.

067 - 1. No.
067 - 2. Yes.
067 - 3. Yes.

068 - 1. b, f, i.
068 - 2. g.
068 - 3. d.
068 - 4. g.
068 - 5. c, k.
068 - 6. b, f.
068 - 7. e.
068 - 8. l, a.
068 - 9. h.
068 - 10. g.
068 - 11. f.
068 - 12. f, i.

069 - 1. Variation of film processing from one day to the next and from one processor to another.

069 - 2. Expose a filmstrip to light and process it. Determine various densities from the film with a densitometer and record the information on a chart.

070 - 1. A sensitometer produces equal repeated exposures from one day to the next. Exposure from a radiographic unit varies from day to day.
070 - 2. To prevent minor variations from one box of film to another from affecting film densities.
070 - 3. Immediately, because delays can affect the resulting film densities.

071 - 1. B.
071 - 2. C; day 6 or 7; day 10.
071 - 3. You should be alerted that something may be wrong with the processor at days three and four. On day seven the density is outside the tolerable limits; you would still suspect processor trouble but should wait another day to see if the density returns to normal. The density is stable and well within the tolerable limits.

072 - 1. Increasing developer temperature.
072 - 2. Increasing exposure to safelights.

073 - 1. Delayed recognition of potential problems.
073 - 2. Place the daily strip alongside a base filmstrip from the film manufacturer and compare the density steps.
073 - 3. Contrast. Because you must compare the difference between density steps rather than the actual step densities.

074 - 1. A.
074 - 2. A.
074 - 3. Yes, A and C.
074 - 4. A.
074 - 5. High developer temperature, high replenishment rates, and long immersion time.

CHAPTER 5

075 - 1. T.
075 - 2. F. Experience is perhaps more advantageous than any other factor.
075 - 3. T.
075 - 4. T.
075 - 5. T.

076 - 1. Diagnostic; minimum.
076 - 2. The mAs; kVp; both.
076 - 3. It reduces the possibility of error and teaches you how each factor affects the radiograph.
076 - 4. Yes. Good technique charts usually provide sufficient kVp and mAs for a particular part. Consequently, you can usually change either the kVp or mAs to correct a density problem.
076 - 5. Background density, image density, and exposure factors used.
076 - 6. mAs.
076 - 7. Underexposed; overexposed.
076 - 8. Check, results.

077 - 1. Refer to the characteristic curve of your brand of X-ray film.
077 - 2. Considerably more mAs is required to increase the density.
077 - 3. Double the mAs to double the density—halve the mAs to halve the density.
077 - 4. Add 15 percent of the kVp to double the density and subtract 15 percent to halve the density.

078 - 1. The visible difference in density between the structures on a radiograph.
078 - 2. Radiograph A.
078 - 3. Radiograph B.
078 - 4. Radiograph C.
078 - 5. Radiograph A.
078 - 6. Radiograph C.

079 - 1. By affecting the selective absorption of X-ray photons, which is the difference in absorption by the various structures.
079 - 2. The radiograph of the distal portion of the leg. Because the *difference* between the thickness of the distal tibia and fibula is less than the difference between the thickness of the proximal tibia and fibula. Consequently, there is less difference in photon absorption.
079 - 3. Bone, Fat. Because their atomic numbers are the highest and lowest, respectively, and the higher the atomic number of a structure, the more photon absorption due to the photoelectric effect.
079 - 4. Radiograph B.
079 - 5. Radiograph C.
079 - 6. Lower.

080 - 1. Radiograph C.
080 - 2. Radiograph B.
080 - 3. Radiograph A.
080 - 4. Radiograph A.

081 - 1. An even distribution of density, usually over the entire film, which is not caused by the selective absorption of photons.
081 - 2. It lowers the contrast.
081 - 3. It can increase the density to a point where we cannot distinguish the difference between densities.

082 - 1. 20 mAs and 92 kVp.
082 - 2. 80 mAs and 68 kVp.

083 - 1. 150 mA.
083 - 2. 1/10 sec.

084 - 1. 18 mAs.
084 - 2. 18 inches.
084 - 3. 44 inches.
084 - 4. 25 mA.
084 - 5. 1/20 sec.

085 - 1. It must produce consistent results. See to it that technique charts are available and used by all personnel.
085 - 2. It must provide sufficient exposure of the film. Sufficient mAs and kVp must be established for each part.
085 - 3. It must be flexible. The mAs and kVp should be selected between the extremes of the values available on your X-ray machine control panel to permit change.
085 - 4. It must provide the desired contrast. Use the kVp range which will accomplish this.

086 - 1. mAs.
086 - 2. The thickness of the part.
086 - 3. Contrast varies from one examination to another.
086 - 4. It is easy to apply.
086 - 5. By trial and error.
086 - 6. One; four
086 - 7. It allows you to determine the kVp by mental calculation rather than by referring to the technique chart for each measurement of a part.
086 - 8. 78 kVp.
086 - 9. 40.

087 - 1. T.
087 - 2. T.
087 - 3. T.
087 - 4. F. Contrast is consistent for all examinations of the same part. It may vary from part to part.
087 - 5. F. Preparation is difficult and time-consuming.

088 - 1. Low mAs and high kVp (the highest kVp which will produce radiographs to satisfy your radiologist).
088 - 2. Lower patient dosage, less heat units per exposure to the X-ray tube target, and greater exposure latitude.

089 - 1. 71 kVp.
089 - 2. 100 kVp.
089 - 3. 102 kVp.
089 - 4. 20 mAs.
089 - 5. 20 percent.
089 - 6. a. 30 percent.
  b. 70 percent.
  c. 75 percent.

CHAPTER 6

090 - 1. The person involved and his state of health. An elderly person or someone in poor health is particularly susceptible.
090 - 2. Part of the body involved. The heart or brain are especially susceptible.
090 - 3. Time of exposure. The longer the exposure, the greater the effect.
090 - 4. Type of current. DC is more dangerous than AC.

091 - 1. T.
091 - 2. F. A fuse is designed to protect the electrical circuit.
091 - 3. T.
091 - 4. F. Same as exercise 2 above.
091 - 5. F. Replacing a fuse with one of a higher rating is *NEVER* permitted.
091 - 6. F. Have the medical equipment repairman replace the fuse and find out the cause of the blown fuse before using the machine.
091 - 7. T.

092 - 1. Proper grounding of the equipment.
092 - 2. the housing is isolated from the electrical circuits. To prevent current from being introduced into the housing.
092 - 3. Probably not. The current returns to earth through the ground wire because it is the path of least resistance.
092 - 4. Probably not.
092 - 5. You would be shocked. Because you connected yourself between the circuit in the initial appliance and ground potential, you now are part of a completed circuit, and current would easily flow through your body.

092 - 6. a. Loose, bent, or otherwise defective power plugs.
  b. Frayed or cracked power cords or other outside electrical wires.
  c. The use of "cheater plugs."
  d. Missing ground prong on the power plug.

092 - 7. Do not use the piece of equipment. Report the finding to a medical equipment repairman.

093 - 1. Very little. Because the resistance of the skin is bypassed by the catheter.
093 - 2. One one-thousandth.
093 - 3. Yes. There is danger from leakage current, which can exist even if no wiring defects are present.
093 - 4. The contrast medium in the catheter. Yes.
093 - 5. The patient is grounded through the film changer and/or X-ray table. Yes.
093 - 6. Yes. Because there may be a difference in potential between the injector and film changer, which could cause current to flow through the patient.

094 - 1. Insure that all the electrical equipment in the room is grounded to the same ground potential. Have the room rewired if necessary.
094 - 2. Do not alter power plugs, wiring, or anything affecting the equipment ground.
094 - 3. Have heavy duty, three-way line plugs installed on all power cords.
094 - 4. Inspect the equipment before each examination for frayed line cords, broken plugs, deteriorated insulation, or other equipment defects.

095 - 1. Darkroom; shock.
095 - 2. The tank is probably grounded, and when in contact with it, you are at ground potential.
095 - 3. Yes. Because you have placed yourself into a circuit and are subject to shock if the dryer wiring is defective.
095 - 4. Hangers; water; floor.
095 - 5. Touching only one electrical appliance at a time. It can help prevent your body from being at ground potential.
095 - 6. Turn; off.
095 - 7. Keep water mopped up from the floor, and keep your hands as dry as possible.

096 - 1. T.
096 - 2. T.
096 - 3. F. You *must* make sure the object you use to separate him from the source is nonconductive. Dry wood, clothing, rope, a blanket, or other similar materials should be used.
096 - 4. T.
096 - 5. F. The head position is not important for closed-chest heart compression, but is important for mouth-to-mouth. During mouth-to-mouth the head should be in the "sword-swallowing" position.
096 - 6. T.
096 - 7. T.
096 - 8. F. It should be depressed 1½ to 2 inches.
096 - 9. T.
096 - 10. T.

097 - 1. They are absorbed by the patient.
097 - 2. By removing a good portion of the low-energy photons.
097 - 3. Filtration built-into the X-ray tube. It is usually from 0.3 mm to 0.5 mm aluminum equivalency, depending upon the type of tube.
097 - 4. 0.2 mm.
097 - 5. 1.5 mm.
097 - 6. 2.0 mm.
097 - 7. By reducing the number of low-energy photons and the minimum photon energy.

098 - 1. They increase the mean energy of the beam.
098 - 2. They permit a short exposure time, thereby reducing repeat radiographs because of part motion.
098 - 3. They provide more exposure latitude, which reduces repeat radiographs due to the use of incorrect exposure factors.

099 - 1. It limits the area of exposure to that necessary to visualize the part under study. It prevents repeat radiographs due to excessive film fog.
099 - 2. The outer limits of the X-ray field.
099 - 3. Only that it was larger than the film. The collimator could have been wide open.
099 - 4. There is no particular size. It depends upon the film size, patient size, and part under study. The important thing is for you to see a border of some size on most radiographs.

100 - 1. Hips, femurs, and lumbar spines.
100 - 2. Abdomens, intravenous pyelograms, sacrum, and coccyx.
100 - 3. Make sure the shield does not interfere with the examination, and do not substitute the shield for proper beam collimation.

101 - 1. Less exposure is required to produce the radiograph.
101 - 2. Some detail.
101 - 3. Use medium or slow screens for body parts requiring maximum detail and high-speed screens for other radiographs.

102 - 1. C.
102 - 2. C.
102 - 3. The shorter the developing time, the greater the patient exposure.
102 - 4. The time recommended by the film manufacturer.

103 - 1. Never expose yourself to the primary beam.
103 - 2. Always remain behind a protective barrier when making an exposure.
103 - 3. Stay as far away from the radiation source as possible.
103 - 4. Wear a protective apron during fluoroscopy.

104 - 1. Insure that all personnel under your supervision are thoroughly indoctrinated in the proper use of the dosimeter.
104 - 2. You are responsible for the proper use of the dosimeter.

105 - 1. T.
105 - 2. F. The belt is at waist level and the dosimeter is worn *above* the waist.
105 - 3. F. It is worn during fluoroscopy beneath the protective apron.
105 - 4. T.
105 - 5. T.
105 - 6. F. It assesses exposure to the head and lens of the eye.
105 - 7. F. It is worn in addition to the other dosimeters.
105 - 8. F. Dosimeters are used only for the purpose specified and at the location specified.
105 - 9. F. As a general rule this is true, but you must wear your dosimeter when performing portable radiographs.
105 - 10. F. They must be stored outside a radiation area.
105 - 11. T.
105 - 12. F. The identification can be placed on the front as long as the window is not covered.
105 - 13. F. The chest dosimeter only is used to measure whole-body exposure.

AU GAFS,AL.(751842)1800

STOP- **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 OR NUMBER 2 PENCIL.**

90370 01 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE
RADIOGRAPHIC FUNDAMENTALS

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor. If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

10-5

Multiple Choice

1. (001) The movement of electrons through a conductor constitutes an electrical

   a. charge. c. voltage.
   b. current. d. resistance.

2. (002) Material A has one valence electron, material B has three valence electrons, and material C has four valence electrons. Classify the materials as conductors, semiconductors, or insulators.

   a. A—conductor; B—semiconductor; C—insulator.
   b. A—conductor; B—conductor; C—semiconductor.
   c. A—insulator; B—semiconductor; C—conductor.
   d. A—insulator; B—conductor; C—semiconductor.

3. (003) The standard symbol used for voltage is

   a. E. c. R.
   b. I. d. P.

4. (004) In the value "10Ω," the "10" refers to the amount of resistance (R) indicated and the symbol "Ω" is read

   a. "amps." c. "volts."
   b. "ohms." d. "watts."

5. (005) The resistance of a wire conductor as computed for a circuit depends on all of the following except

   a. temperature. c. type of insulation.
   b. length. d. cross-sectional area.

6. (006) How much resistance is present in a circuit if the voltage is 220 and the current is 10 amperes?

   a. 0.04Ω. c. 210Ω.
   b. 22Ω. d. 2,220Ω.

7. (007) If, on a schematic of an electrical circuit, a number is shown alongside a symbol of a battery, the number represents the

   a. battery voltage. c. number of cells.
   b. battery current. d. number of circuit components.

8. (008) All of the following are basic electrical circuits except

   a. resistance-parallel. c. parallel.
   b. series-parallel. d. series.

9. (009) The reciprocal method is one of several for determining the

   a. total current in a series circuit.
   b. effective voltage in a parallel circuit.
   c. effective resistance in a parallel circuit.
   d. total voltage in a series-parallel circuit.

10. (010) Redrawing a circuit before making calculations is an effective and easy method to

   a. find the total resistance in a series-parallel circuit.
   b. determine the voltage drop across several resistors.
   c. determine the total current in a complicated circuit.
   d. find the voltage and current values of a parallel circuit.

11. (011) The strength of a magnetic field depends upon the

   a. location of the poles.
   b. relative size of the ends of the bar.
   c. number of lines of force per unit area.
   d. direction of travel of the lines of force.

12. (012) In an unmagnetized iron bar, the magnetic dipoles of the material are

   a. arranged at random.
   b. pointed toward the periphery.
   c. molecular in size and have no north or south poles.
   d. arranged so that their north poles point in one direction.

13. (013) A straight, current-carrying conductor has a magnetic field

   a. with few lines of force.
   b. only if the current is DC.
   c. with no north or south poles.
   d. which does not expand or collapse.

14. (014) All of the following factors affect the strength of the magnetic field of a coil except the

   a. iron core.
   b. retentivity.
   c. turns per inch.
   d. current magnitude.

15. (015) The "centering effect" of an iron core is best described as

   a. the centering of a lead core to a current-carrying coil.
   b. an iron core not remaining inside a current carrying coil.
   c. an iron core is inside a wire coil that cannot be removed unless current is applied to the coil.
   d. a core suspended inside a wire coil, with current causing the core to center itself to the length of the coil.

16. (016) A relay operates on the principle that

   a. electromagnetism increases current flow.
   b. arcing in high-voltage circuits is dangerous.
   c. an electromagnet attracts magnetic substances.
   d. a current-carrying coil has two magnetic fields if the current is AC.

17. (017) The coil in a permanent-magnet, moving-coil meter is caused to rotate by the

   a. coil bar attracted to the north pole.
   b. magnetic field of the needle repelling the electromagnetic south pole.
   c. poles of an electromagnet opposing the poles of a permanent magnet.
   d. permanent magnet aligning itself with the magnetic field of the electromagnet.

18. (018) Which one of the following statements best compares current flow of AC to that of DC?

    a. AC flows from negative to positive; DC flows from positive to negative.
    b. Both flow from negative to positive; AC constantly changes directions.
    c. Both flow from positive to negative; direction of flow is the same.
    d. DC constantly changes in value; AC does not.

19. (019) The sine wave of AC is a good representation of the

    a. actual current plotted aginst time.
    b. actual voltage plotted through 360°.
    c. changing values plotted against time.
    d. specific voltage and current values in relation to the resistance.

20. (020) Which one of the factors listed below is not a requirement for electromagnetic induction?

    a. Conductor.
    b. Iron core.
    c. Magnetic field.
    d. Relative motion.

21. (021) Mutual and self-induction occur without moving the conductor due to

    a. movement of the iron core.
    b. the consistent value of DC.
    c. the expanding and collapsing magnetic field.
    d. the high current generated in the wire coil.

22. (022) Transformer action can be defined as the process of

    a. conducting current and voltage in an AC circuit.
    b. reducing voltage and current values by mutual induction.
    c. increasing the electrical energy in a circuit by self-induction.
    d. transferring electrical energy from one circuit to another by electromagnetic induction.

23. (023) Improper adjustment of the line voltage compensator on the autotransformer may result in

    a. lower tube capacity.
    b. inaccuracy of the timer.
    c. AC across the X-ray tube.
    d. light or dark radiographs.

24. (024) Three-phase AC produces how many pulses per cycle across the X-ray tube?

    a. One or two.
    b. Six or twelve.
    c. Two or twelve.
    d. One, two, or six.

25. (025) Which one of the following statements pertains to the relationship between voltage waveform and electron energy?

    a. Twelve-pulse produces higher maximum electron energy than does six-pulse.
    b. Twelve-pulse produces higher average electron energy than does two-pulse.
    c. One-pulse produces higher average electron energy than does two-pulse.
    d. Six-pulse produces higher maximum electron energy than does two-pulse.

26. (026) Average photon energy from a three-phase generator is higher than that from a single-phase generator because in the former

    a. the current is lower.
    b. the current is higher.
    c. the peak voltage is higher.
    d. average electron energy is higher.

27. (027) The intensity of the X-ray beam is higher from a three-phase generator than that from a single-phase generator when equal tube currents are used because

    a. image-forming radiation is continuously produced.
    b. low-energy photons are continuously produced.
    c. high-energy photons are produced three-fourths of a given time period.
    d. non-image-forming radiation is produced only at the bottom of the wave.

28. (028) If 100 kVp is used for a radiograph on a three-phase machine, what kVp should be used for the same radiograph on a single-phase machine?

    a. 85.
    b. 90.
    c. 115.
    d. 120.

29. (029) How does tube capacity compare between single-phase and three-phase tubes for exposure times between one-half and one second?

    a. Lower with three-phase.
    b. Higher with three-phase.
    c. They are approximately equal.
    d. Lower with three-phase when low tube voltage is used.

30. (030) Use of the STAND-BY button on the exposure switch should be kept to a minimum in order to

    a. reduce off-focus radiation.
    b. prevent heat buildup in the anode.
    c. reduce surface etching of the target.
    d. prevent vaporization of the tube filament.

31. (031) Which one of the following is considered the chief advantage of an X-ray tube with a biased focal spot?

    a. Exposures are grid controlled.
    b. It permits higher heat loading.
    c. Accumulative heat units are lower.
    d. It prevents a double image on the film.

32. (032) Two advantages of a grid-controlled X-ray tube are

    a. short exposures and lower patient dosage.
    b. short exposures and lower photon energies.
    c. less heat units per exposure and higher photon energies.
    d. more detail on an angiogram and lower photon energies.

33. (033) How many heat units are generated in a three-phase generator if the exposure factors are 100 mA, 1 sec, and 85 kVp?

    a. 850.
    b. 8,500.
    c. 11,100.
    d. 11,475.

34. (034) Which one of the following can be determined form a single-exposure tube rating chart?

    a. mA and kVp only.
    b. Heat units only.
    c. mA, kVp, and seconds.
    d. kVp and seconds and heat units.

35. (035) You are required to use an angiographic rating chart to determine whether or not the total number of exposures per angiographic examination exceeds the maximum limits of the tube. You have this data available from your radiologist: 4 exposures per second, for 13 seconds. The exposure factors are 500 mA, 1/20 sec, and 80 kVp. Which statement below is not a correct procedure?

a. Use 2000 as the maximum load per exposure.
b. Move up to the total number of allowable exposures.
c. Find 52 exposures per second on the left margin of chart.
d. Move across that column to the maximum load per exposure.

36. (036) On an anode cooling chart, you find the cooling time between examinations by

a. comparing the mAs with the kVp.
b. looking at the readings along the left margin.
c. following the cooling curve and correlating the curve with the horizontal scale.
d. following the correct cooling curve, then performing a calculation, and following another curve before taking a second reading.

37. (037) What should be adjusted on the X-ray machine control panel to change the penetrative ability of the X-ray beam?

a. mA.
b. kVp.
c. mAs.
d. Exposure time.

38. (038) Which of the following X-ray machine controls should be used to alter the number of photons per square inch in the X-ray beam?

a. mA and kVp only.
b. mA and exposure time only.
c. mA, kVp, and exposure time.
d. kVp, exposure time, and line voltage compensator.

39. (039) The inverse square law affects the primary beam by

a. eliminating the low-energy photons.
b. regulating the mean energy of the beam.
c. affecting the number of photons per unit area.
d. increasing the intensity on the cathode side of the tube.

40. (040) The anode heel effect is caused when

a. target material absorbs photons.
b. some photons have less energy than others.
c. a small focal spot emits a heterogeneous beam.
d. a large focal spot provides greater variation in beam intensity.

41. (041) Which of the following anode angles provides the greatest variation in beam intensity?

a. 10°.
b. 12°.
c. 15°.
d. 17°.

42. (042) Which of the following focal spots should be used to provide the best detail?

a. 0.3 mm.
b. 0.5 mm.
c. 1.5 mm.
d. 2.0 mm.

43. (043) The factor most important when deciding what focal spot to use with a particular examination is the

a. necessity of detail.
b. capacity of the tube.
c. contrast scale desired.
d. number of exposures required.

44. (044) If a radiograph of the knee shows too much magnification, which one of the following changes could be made to decrease the magnification?

a. Decrease the FFD.
b. Increase the FFD.
c. Decrease the exposure.
d. Increase the part-film distance.

45. (045) Why should distortion be kept to a minimum on a radiograph?

a. Interpretation is easier.
b. Distortion decreases penumbra.
c. Linear fractures are obscured.
d. Enlargement of a part can indicate pathology.

46. (046) A practical way to provide contrast between the gallbladder and surrounding structures is to

a. decrease the contrast.
b. increase the filtration.
c. double the size of the projected area.
d. use a collimator to restrict the field size.

47. (047) AFM 161-38 requires that all X-ray machines have a collimator except

a. therapeutic units.
b. multipurpose units.
c. special-purpose units.
d. general-purpose units.

48. (048) A required collimator must be adjusted if any side of an X-ray field deviates by more than what percent of the FFD?

a. 2.
b. 4.
c. 6.
d. 10.

49. (049) Which one of the following body parts may normally be radiographed with or without a grid?

a. Chest.
b. Wrist.
c. Skull.
d. Pelvis.

50. (050) The grid radius is of importance primarily because of its effect on the

a. FFD.
b. tube alignment.
c. efficiency of the grid.
d. height of lead strips and interspaces.

51. (051) The greatest advantage of a grid with many lines per inch is that the lead strips are less visible on the radiograph and therefore

a. give better constrast.
b. have more lead content.
c. interfere less with interpretation.
d. can be safely moved during exposure.

52. (052) The use of a crossed grid as compared to a linear grid

a. has an unlimited usage.
b. has less lead in the grid.
c. has an effective ratio twice its nominal ratio.
d. permits the tube to be angled in unlimited ways.

53. (053) Normally, the type of grid to use to prevent grid lines at very short exposure times would be a

a. moving Potter-Bucky.
b. Potter-Bucky of any type.
c. recipromatic Potter-Bucky.
d. reciprocating Potter-Bucky.

54. (054) Grid efficiency refers to the amount of scatter radiation absorbed compared to the amount of

a. photon scatter.
b. microline grid exposure.
c. lateral decentering used.
d. primary radiation absorbed.

55. (055) Lateral decentering of an X-ray tube causes

a. a fog over the decentered area.
b. an even fog over the entire radiograph.
c. an even loss of radiographic density over the near side of the film.
d. an even loss of radiographic density over the entire film.

56. (056) Which one of the following actions should be taken to determine the tolerance of grids if focal ranges are not specified by the manufacturer?

a. Apply more kVp.
b. Increase the mAs.
c. Use a densitometer.
d. Obtain the manufacturer's recommendations.

57. (057) If a grid radiograph shows a loss of density on one lateral margin of the film, which of the following types of decentering was likely present at the time of exposure?

a. Focus decentering.
b. Lateral decentering only.
c. Distance decentering only.
d. Lateral and distance decentering.

58. (058) Select the maximum tube angle which can be allowed if you desire to avoid a noticeable loss of density over the entire radiograph in a case where the grid ratio is 16:1.

a. 1°.
b. 3°.
c. 6°.
d. 8°.

59. (059) Which one of the following indicates that the composition of the X-ray film has been especially adapted for use in 90-second processors?

a. Polyester base.
b. Two subcoatings.
c. Cellulose acetate base.
d. Emulsion on one side only.

60. (060) Which type of X-ray film provides excellent detail for small parts and because of its thick emulsion requires longer processing?

a. Dental only.
b. Screen only.
c. Nonscreen.
d. Both dental and screen.

61. (061) A densitometer shows that part "X" of a radiograph has a density of 1.0, while part "Y" has a density of 3.0. Which statement below compares the incident light transmitted through "X" to the incident light transmitted through "Y"?

a. 1 percent to 3 percent.
b. 3 percent to 1 percent.
c. 0.1 percent to 10 percent.
d. 10 percent to 0.1 percent.

62. (062) Which one statement below is typical of the characteristic curve of an X-ray film used to determine the specific mAs changes necessary to raise or lower a radiograph density?

a. Density is plotted on the horizontal axis.
b. Log relative exposure is plotted on the vertical axis.
c. Values of mAs that can be applied to the scale are limited.
d. The horizontal axis, "log relative exposure," represents the mAs required to change density.

63. (063) The inherent film fog, as determined from reference to the toe of the film's characteristic curve and judged on a general basis, is excessive if it exceeds a density of

a. 0.2
b. 1.0.
c. 1.5.
d. 2.0.

64. (064) The name of the layer of material of an intensifying screen designed to expose the film is called a

a. base.
b. phosphor.
c. protective coating.
d. reflecting material.

65. (065) As the speed of intensifying screens become higher, there is a resultant

a. decrease in the life of the X-ray tube.
b. reduction in radiographic detail and clarity.
c. increase in the transmission of radiation to the patient.
d. increase in radiographic-exposure time necessary for clarity.

66. (066) A part of the process of making a valid screen-film-contact test consists in inspection of a

a. wire mesh image.
b. voltmeter reading.
c. densitometer reading.
d. thickness-gauge measurement.

67. (067) If, during a valid screen-lag test, half of the film is found to be exposed while the other half is not, it may be concluded that

a. screen lag is present.
b. screen lag is not present.
c. fluorescence stopped at the time of esposure.
d. no evaluation can be made without the name of the test.

68. (068) Exposed crystals in films are changed to black metallic silver during film processing by

a. sodium sulfite.
b. phenidone, metol, and hydroquinone.
c. potassium alum and sodium carbonate.
d. gluteraldehyde, acetic acid, and sodium thiosulfate.

69. (069) To insure consistent high-quality production of radiographs, each processor should be checked daily using a

    a. cleaning agent.
    b. voltmeter only.
    c. densitometer only.
    d. sensitometric film strip, a densitometer, and a recording chart.

70. (070) One requirement pertaining to the use of the sensitometer and radiographic film while conducting a processor evaluation test includes

    a. reserving one box of film for the evaluation.
    b. substitution of a radiographic unit for a sensitometer.
    c. exposing film every two days and processing as a matter of convenience.
    d. insuring all procedures remain the same.

71. (071) To measure the density in evaluating filmstrips, a density step between 0.9 and 1.2 is selected because these densities

    a. cover the average normal densities.
    b. comprise the allowable upper limits of densities.
    c. comprise the allowable lower limits of densities.
    d. are located on the portion of the characteristic curve most sensitive to changes in processing.

72. (072) The base fog of a filmstrip is easily measured by

    a. the contrast of two exposed steps.
    b. looking at the manufacturer's specifications.
    c. the density of the unexposed density step.
    d. increasing the developer temperature to a high value.

73. (073) If processing is accomplished without using a densitometer, the most difficult comparison to make is of

    a. density.
    b. base fog.
    c. contrast.
    d. base fog coupled with density.

74. (074) Underdevelopment that permits variations between processors can be caused by such factors as

    a. low replenishment rates.
    b. high replenishment rates.
    c. low fixer immersion time.
    d. high developer temperature.

75. (075) As measured with a densitometer, the average density for most radiographs should be approximately

    a. 0.5.
    b. 1.5.
    c. 2.5.
    d. 25.

76. (076) To change density with kVp or mAs, all of the following should be considered _except_

    a. image density.
    b. background density.
    c. exposure factors used.
    d. increase mAs if too little kVp is used.

77. (077) The most reliable and accurate way to determine the exact mAs change required to make a specific change in the film density is to

   a. use a rule of thumb.
   b. make mathematical calculations.
   c. double or halve the mAs to double or halve the density.
   d. refer to the characteristic curve of the brand of X-ray film used.

78. (078) In radiology, "the visible difference in density between areas or structures on a radiograph" is defined as

   a. contrast.
   b. high contrast.
   c. long-scale contrast.
   d. short-scale contrast.

79. (079) The three factors—structure thickness, atomic number, and density—affect the contrast on a radiograph by

   a. eliminating film fog.
   b. negating the affects of film contrast.
   c. affecting the selective absorption of the photons.
   d. shortening the exposure time thereby affecting selective absorption.

80. (080) The one most important factor affecting the selective absorption and contrast on a radiograph is best designated as

   a. energy.
   b. wavelength.
   c. penetrative ability.
   d. kVp selected on the control panel.

81. (081) Film fog, as it occurs on radiographs to reduce their contrast, is caused by all of the following except

   a. scatter radiation.
   b. improper processing.
   c. deliberate film exposure.
   d. exposure of the film to either light or to radiation leaks.

82. (082) A radiograph made with 100 kVp and 30 mAs is properly exposed but lacks contrast. Which of the following values should be used to produce a second radiograph that is equal in overall density to the first with proper contrast?

   a. 50 kVp and 60 mAs.
   b. 85 kVp and 60 mAs.
   c. 110 kVp and 15 mAs.
   d. 115 kVp and 15 mAs.

83. (083) The mA-sec formula that you should use in your computation to control undesirable motion and thus enhance image detail is

   a. $\underline{mA_2}:\underline{mA_1}::\underline{sec_2}:\underline{sec_1}$.
   b. $\underline{mA_1}:\underline{mA_2}::\underline{sec_2}:\underline{sec_1}$.
   c. $\underline{mA_1}:\underline{sec_1}::\underline{mA_2}:\underline{sec_2}$.
   d. $\underline{mA_2}:\underline{mA_1}::\underline{sec_2}:\underline{sec_1}$.

84. (084) A technique chart may specify a technique of 14 mAs using a 56-inch FFD; however, if because of limitations, it may become necessary to use a 28-inch FFD. Such a requirement will then necessitate a new mAs of

   a. 2.5.
   b. 3.5.
   c. 7.0.
   d. 56.

85. (085) Which one of the following four basic requirements for establishing a standard system of exposure factors would be sought in keeping both the mAs and the kVp within a range from which either may be increased or decreased?

   a. Flexibility.
   b. Consistent results.
   c. Desired contrast range.
   d. Sufficient exposure of film.

86. (086) One absolute requirement for use of a chart employing variable kVp techniques is to

a. also vary the mAs.
b. insist that no two individuals use the same chart.
c. know the part thickness in centimeters along the path of the CR.
d. make a two-kVp change for each centimeter of part change, without exception.

87 (087) All of the following are descriptive of the "fixed" kVp technique except

a. contrast is consistent for all body parts.
b. the system is fast falling into disrepute.
c. mAs varies depending upon the size of the part.
d. a change from 40 to 50 mAs for a larger part is appropriate.

88. (088) All of the following statements list advantages of using high kVp techniques except

a. there is greater exposure latitude.
b. there is less absorption of photons by patient.
c. X-ray tube is subjected to fewer heat units per exposure.
d. the time and effort it takes to prepare the chart used is negligible.

89. (089) Changes of exposure necessitated by the presence of a cast or the patient's age require reference to tabular data called

a. compensatory factors.
b. compensation factors.
c. collective factors.
d. collateral factors.

90. (090) The amount of current constituting a lethal shock varies with all of the following except

a. type of current.
b. ionizing radiation.
c. age of the patient.
d. part of body involved.

91. (091) A burned out fuse in an X-ray machine should be replaced

a. by one of the same rating.
b. with one of a lower rating.
c. with one of a higher rating.
d. by a medical equipment repairman.

92. (092) An important safeguard to protect service personnel and patients from electrical shock in case radiology equipment shorts the operating current to the housing is to

a. properly ground the equipment.
b. replace the fuse with a smaller one.
c. rely on the fuse for adequate protection.
d. touch both its housing and another grounded piece of equipment simultaneously.

93. (093) During angiography, in which a catheter is inserted into the blood stream, what measure of the lethal skin current is required to produce ventricular fibrillation?

a. 1/10.
b. 1/100.
c. 1/1,000.
d. 1/10,000.

94. (094) An electrically safe atmosphere for an angiographic patient can be created by

    a. using nonconductive contrast media.
    b. grounding all electrical equipment to metal water pipes.
    c. using only three-prong, heavy-duty line plugs when cords are frayed.
    d. grounding all electrical equipment to the same ground potential.

95. (095) An effective precaution to help prevent electrical shock while manually processing films in the darkroom is to

    a. not turn the dryer switch ON.
    b. work with dry hands and on a dry floor.
    c. always simultaneously contact the processing tank and the dryer.
    d. make certain the dryer housing is not isolated from the power line.

96. (096) If another person accidently comes into contact with a hot wire and is thereby knocked unconscious and frozen to the circuit, the very first action to be taken is

    a. turn the power OFF.
    b. seek additional help.
    c. phone for a physician.
    d. pull the victim from the electrical source.

97. (097) Filtration of the X-ray beam lowers the patient's exposure by removing

    a. most of the medium energy photons.
    b. the aluminum equivalency of the tube.
    c. all of the low-energy photons and consequently lowering the patient's absorbed dose.
    d. a portion of the low-energy photons and consequently increasing the mean energy of the primary beam.

98. (098) High kVp techniques reduce patient exposure in all of the following ways except to

    a. increase the mean energy of the beam.
    b. lengthen the scale of contrast.
    c. provide more exposure latitude.
    d. permit shorter exposure times.

99. (099) One of the two ways that proper collimation reduces patient's exposure is that it

    a. standardizes a 2-inch unexposed border around the sides.
    b. increases the area of exposure to include significant adjacent areas.
    c. increases film fog, making the X-rays themselves less penetrating.
    d. limits the area of exposure to that necessary for visualizing the part under study.

100. (100) All of the following are important to prevent needless exposure of a patient's gonads except

    a. careful shielding for hip examinations.
    b. use of shielding in addition to collimation.
    c. covering them with lead-rubber shielding material.
    d. placement of shield to insure superimposing over part under study.

101. (101) High-speed films and screens reduce patient's exposure to radiation coupled with a

a. detail loss.
b. contrast loss.
c. gain in exposure time.
d. resultant increase in film fog.

102. (102) From an examination of characteristic curves that relate developing time to patient's exposure, it is possible to conclude that the shorter the developing time the

a. less the patient's exposure.
b. greater the patient's exposure.
c. less need there is for shielding.
d. less effect it has on the patient's absorbed dose.

103. (103) All of the following are valid rules for protecting oneself against radiation except

a. remaining behind a protective barrier.
b. wearing a protective apron during fluoroscopy.
c. staying as far away from the radiaton source as possible.
d. occasionally exposing oneself to the primary beam since scatter is usually less hazardous.

104. (104) Technician responsibilities include

a. repair of issued dosimeters.
b. proper use of the dosimeter issued by a supervisor.
c. routine recording of levels for the personnel dosimeter.
d. checking levels and conditions of issued personnel dosimeters.

105. (105) If a dosimeter is used to record exposure to a localized area, what must be done before it can be worn at any other body site?

a. Replace it.
b. Change the dosimeter film.
c. Recalibrate it for accuracy.
d. Record the localized exposure.

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RADIOLOGY TECHNICIAN

(AFSC 90370)

Volume 2

Osteology and Positioning

Extension Course Institute

Air University

10-5

Preface

WHAT DOES IT take to produce a diagnostic radiograph? Exact technique? Perfect processing? Proper film holder? Good equipment? As you know, it takes all of these factors, plus another very important one—proper positioning. All of the other factors can be perfect, but if the positioning isn't correct, the radiograph may not be diagnostic. As a "five level" you have, no doubt, taken your share of radiographs and realize the importance of proper positioning techniques. You are probably also aware of the fact that osteology and positioning go hand in hand. The ability with which you position the patient is directly related to your knowledge and application of osteology.

As you advance to the "7 level," you will become more and more involved in quality control. You will have to evaluate radiographs and decide whether or not they are diagnostic. If they are not, you must recommend the proper corrective measures to be taken. It is obvious that you will not be able to perform positioning quality control satisfactorily unless you have a good working knowledge of osteology and can apply the correct positioning techniques.

This volume is designed to provide you with information to aid you in quality control. We will include almost a complete review of the osteology because of its importance. Our review of the standard positions will be limited because you should be able to perform them competently already. We will present, in detail, some frequently used special or additional positions. We will also provide you with additional information about the radiograph to help you evaluate the quality of a radiograph as related to positioning.

We do not recommend that you repeat all radiographs that were improperly positioned. There are other considerations, such as patient dosage, time element, and the amount of information revealed by the initial radiograph. We do recommend that you discuss quality control in detail with your radiologist. Get to know what he likes and dislikes and then repeat or accept the radiographs based on his preferences.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to School of Health Care Sciences/MST, Sheppard AFB TX 76311. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of October 1974.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Osteology of the Extremities

WE BEGIN OUR STUDY of osteology with the extremities. Some of the information in this chapter will, no doubt, seem "old" to you because you should already have a good working knowledge of the material. Since you have performed many radiographs of the extremities, you must also realize by now that the effectiveness of your positioning is directly related to your knowledge of anatomy. Therefore, our review of the basic osteology is reasonably complete. We will also present more the detailed osteology that you need to perform at the 7 level.

In this chapter, we will discuss anatomical reference terms, body planes, the lower extremity, including the pelvic girdle, and the upper extremity, including the shoulder girdle.

1-1. Body Planes and Anatomical Reference Terms

In addition to the specific anatomy, you must also know the relationships of the various parts. The imaginary planes of the body are important so, before we discuss the osteology of the extremities, let's quickly review some anatomical reference terms and the body planes.

200. Identify the relative locations of various parts of the body by correctly indicating whether selected statements, pertaining to the location of the parts, are true or false. If you indicate "false," explain your answer.

Anatomical Reference Terms. To avoid any misunderstanding and confusion in describing the location of anatomical structures, we will use the standard body position as a point of reference. This generally accepted standard position is called the "normal anatomical position" or "anatomical position." This position is assumed when the body is standing erect, the arms are hanging at the sides, and the palms of the hands are turned forward (see fig 1-1). When you use anatomical reference terms, you must visualize the body in this position.

"Anterior" and "ventral" refer to the front of the body; "posterior" and "dorsal," to the back. These terms may also be used to indicate relative positions within the body. For the hands, however, "palmar" is used instead of anterior. In describing the feet, "plantar" refers to the sole and "dorsal" to the upper surface. In describing the anterior surface of the forearm and hand, the term "volar" can be used.

"Medial" refers to structures located nearer the midline of the body; "lateral," to those nearer the side. For example, the tibia is medial to the fibula, and the fibula is lateral to the tibia. These terms may also be used to identify surfaces of various structures. For example, the thumb and little finger are located on the lateral and medial aspects of the hand respectively.

"Superior" refers to a position above a particular reference point; "inferior," to a position below a reference point. The thoracic vertebrae are superior to the lumbar vertebrae, and the lumbar vertebrae are inferior to the thoracic vertebrae.

"Proximal" means nearer the attachment of a limb or nearest the point of origin. "Distal" refers to a position remote from the point of attachment or farthest from the point of origin. For example, the shoulder joint is in the proximal arm, and the wrist joint is in the distal arm.

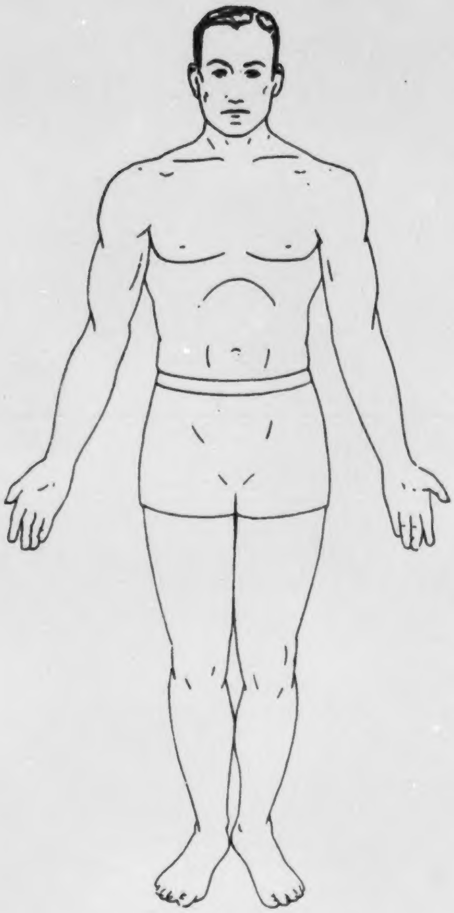


Figure 1-1. Normal anatomical POSITION.

Exercises (200):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. The elbow is proximal to the wrist.

T F 2. The ileum is proximal to the jejunum.

T F 3. The sole of the foot is the plantar surface.

T F 4. The sternum is on the anterior side of the body.

T F 5. The radius is medial to the ulna.

T F 6. The fibula is lateral to the tibia.

T F 7. The fourth cervical vertebra is superior to the first thoracic vertebra.

201. Given definitions of the body planes, match each definition with the plane it describes.

Planes of the Body. The planes of the body are imaginary planes that divide it into sections. They are very useful as reference points for locating anatomical structures. The median or midsagittal plane divides the body into right and left equal halves on its vertical axis. Any of the vertical planes that parallel the median are called sagittal planes. The frontal plane or coronal plane is any vertical plane that divides the body into anterior and posterior portions. The horizontal plane or transverse plane is any plane that divides the body into superior and inferior portions. The level of this plane must be given: for example, the umbilical plane cuts through the body at the level of the umbilicus. Any transverse plane must be at right angles to the median plane. (See fig. 1-2.)

Exercises (201):

Match the body planes in column B with the information in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once.

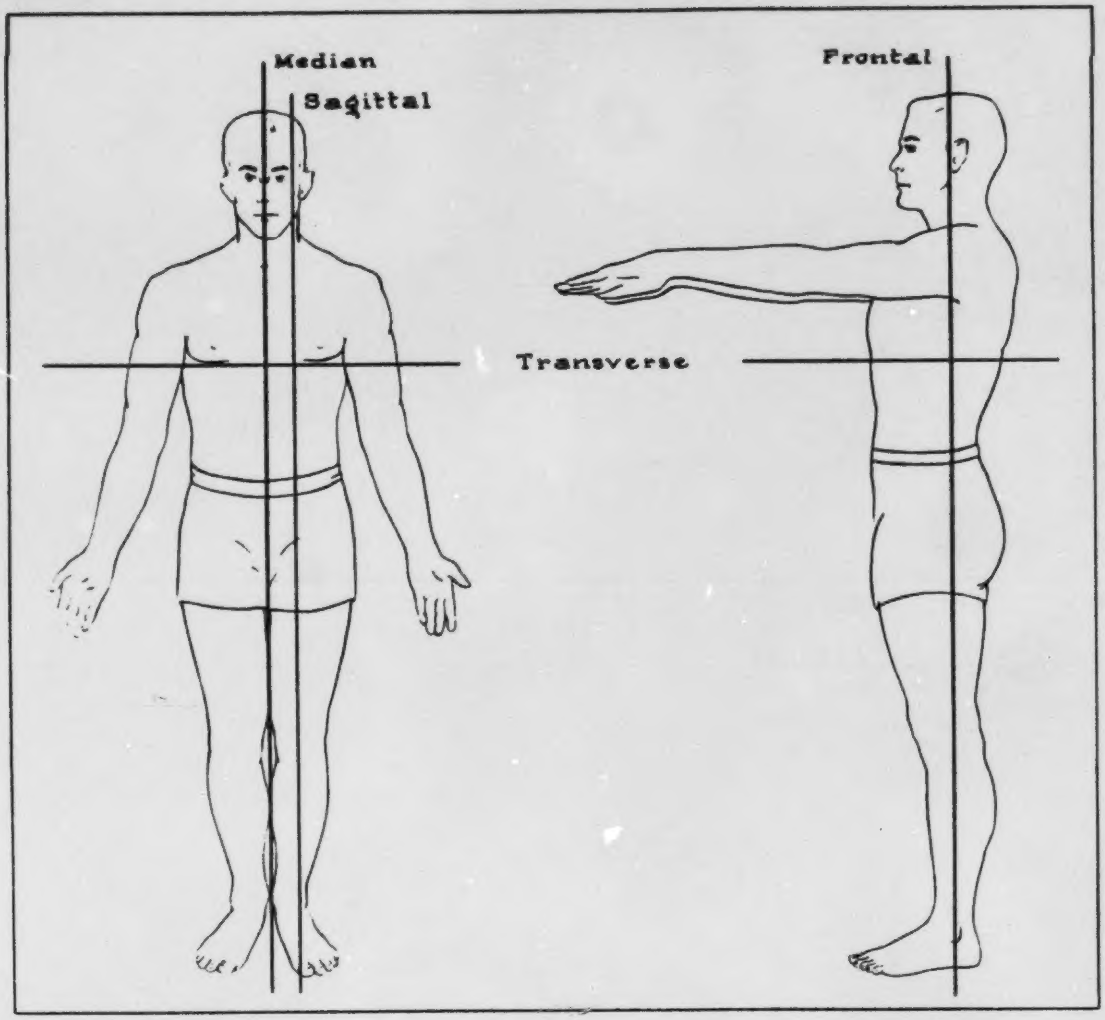


Figure 1-2. Planes of the body.

Column A

___ 1. Divides the right half of the body into medial and lateral portions.
___ 2. Divides the body between the sternum and spine.
___ 3. Divides the body into two equal halves.
___ 4. Separates the umbilicus from the sternum.
___ 5. Is perpendicular to the center of the film for an AP lumbar spine.

Column B

a. Median or midsagittal.
b. Sagittal.
c. Frontal or coronal.
d. Horizontal or transverse.

1-2. The Lower Extremity

This section will cover the toes and foot, the ankle, the leg, the knee and patella, the femur, and the pelvic girdle.

202. Given a list of statements pertaining to the name, location, description, and number of bones and joints of the toes and foot, indicate which are true and which are false. (If you indicate "false," explain your answer.)

The Toes and Foot. The bones of the foot form an arch which, in an architectural sense, strongly resembles the old stone arches. The arch is comprised of wedges, cubes, and long, relatively straight sections, all of which join with each other to provide structural strength and mobility. The skeleton of the foot consists of three parts—the phalanges, the metatarsals, and the tarsal bones. Refer to figure 1-3 as you study the toes and foot.

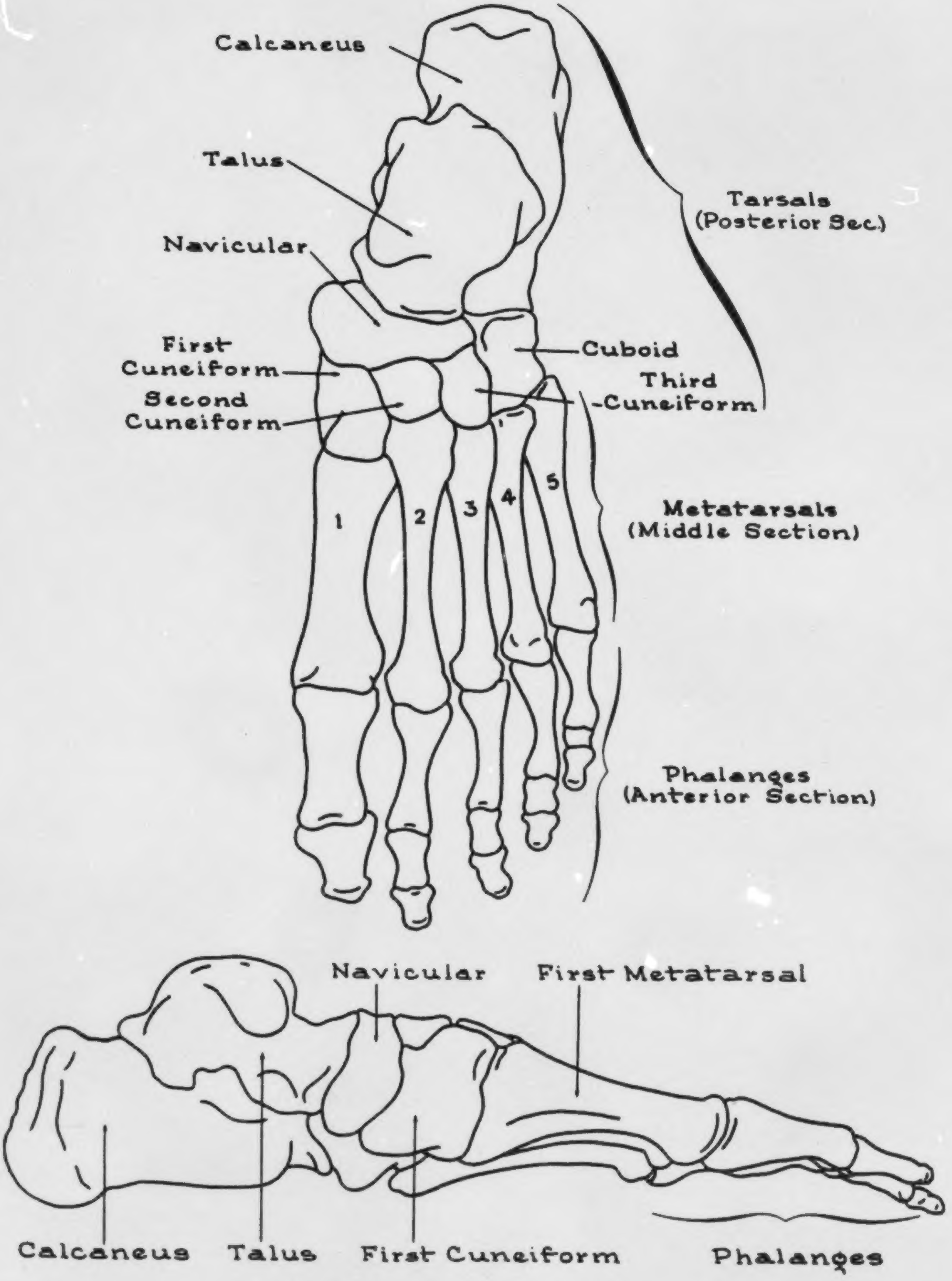


Figure 1-3. Skeleton of the toes and foot.

Phalanges. The phalanges of the toes are arranged and identified in the same manner as are the phalanges of the hand. Each is composed of a body, a head, and a base. The tip of each distal phalanx terminates as the ungual tuberosity, or tuft. Each toe has three phalanges, except the first, which has only two. The phalanges of the first toe join in this way: the distal phalanx joins proximally with the distal end of the proximal phalanx, and the proximal phalanx joins the distal end of the first metatarsal.

The phalanges of the lesser toes join in much the same way as those of the first toe. The proximal portions, or bases, of the distal phalanges articulate with the distal portion, or heads, of the middle phalanges. The bases of the middle phalanges articulate with the heads of the proximal phalanges. The bases of the proximal phalanges, in turn, articulate with the heads of the metatarsals.

Metatarsals. The sole and lower instep are formed by the metatarsal bones, which are classified as short bones and are identified by the numbers one through five from the medial to the lateral sides. Each bone has a body, a base, and a head. The metatarsals join distally with the corresponding proximal phalanges of the toes, and proximally they join the tarsal bones as follows:

a. The first metatarsal joins the distal end of the first cuneiform and the medial surface of the second metatarsal.

b. The second metatarsal joins the medial surface of the first cuneiform, the distal ends of the second and third cuneiforms, and the lateral and medial surfaces of the first and third metatarsals respectively.

c. The third metatarsal joins the distal end of the third cuneiform, the lateral surface of the second metatarsal, and the medial surface of the fourth metatarsal.

d. The fourth metatarsal joins the distal end of the cuboid, the lateral surface of the third metatarsal, and the medial surface of the fifth metatarsal.

e. The fifth metatarsal joins the distal end of the cuboid and the lateral surface of the fourth metatarsal.

Tarsals. The tarsals, which are described below, make up the posterior part of the foot and part of the ankle. Because of their shape, they are classified as irregular bones. Some of them, like the carpals, are often referred to by more than one name.

The first, second, and third cuneiform bones are wedge shaped. They are located directly behind the first, second, and third metatarsals, and in front of the navicular. They are numbered from the medial to the lateral side.

The cuboid is on the lateral aspect of the foot, directly behind the fourth and fifth metatarsal bones.

The navicular (tarsal scaphoid) is on the medial side of the foot, directly behind the cuneiform bones.

The talus (astragalus), through which the body weight is transmitted to the foot, is the second largest tarsal. It is located behind the navicular and slightly higher than the other tarsals. The talus has a head, a neck, and a body. The head is directed slightly medially and upward to articulate with the navicular. The superior portion of the body is a smooth, trochlea-like surface, which articulates with the tibia. The inferior surface has two smooth surfaces, which articulate with the calcaneus. A deep groove, the sulcus tali, separates the smooth surfaces.

The calcaneus (os calcis), the largest of the tarsal bones, is located on the extreme posterior portion of the foot, beneath the talus. The superior surface of its anterior two-thirds supports the talus and receives the body weight transmitted from the talus. The posterior one-third forms the heel. The calcaneal tuberosity lies on the posterior part of the interior surface. It is slightly depressed in the middle and runs to both sides to form the lateral and medial processes. A projection on the superoanterior part of the medial calcaneal surface is called the sustentaculum tali.

Exercises (202):

In the following exercises, indicate whether the following statements are true or false (explain false statements).

T F 1. There are 14 phalanges in the toes.

T F 2. The third toe has two phalanges.

T F 3. The first toe has three phalanges.

T F 4. In the fourth toe, the head of the distal phalanx articulates wth the base of the middle phalanx.

T F 5. There are five metatarsal bones.

T F 6. The fourth metatarsal is located on the lateral side of the third metatarsal.

T F 7. The metatarsals articulate distally with the phalanges.

T F 8. The first, second, and third metatarsals articulate with the cuneiform bones.

T F 9. Only four metatarsals join with another metatarsal.

T F 10. There are seven tarsal bones.

T F 11. The first cuneiform is located on the lateral side of the foot.

T F 12. The talus is the largest tarsal bone.

T F 13. The most superior tarsal bone is the talus.

T F 14. The navicular is on the medial side of the cuboid.

T F 15. The heel bone is the calcaneus.

T F 16. The sustentaculum tali is located on the talus.

T F 17. There are 27 bones of the foot and toes.

203. Describe the anatomical structure of the ankle.

The Ankle. Our discussion of the osteology of the lower extremity continues with the ankle. The ankle is classified as a diarthrodial articulation, or a hinge-type joint. It is formed by the distal articular surface of the tibia, the medial malleolus, the talus, and the lateral malleolus of the fibula. These bony structures form a "mortise"—a preshaped and fitted joint—which is held in place by various ligaments and muscle tissue. The distal articular surface of the tibia and the superior articular surface of the talus form the horizontal portion of the mortise. The medial malleolus, which is continuous with the distal portion of the tibia, articulates with the medial aspect of the talus and forms the medial side of the mortise. The lateral malleolus of the fibula articulates with the lateral aspect of the talus and forms the lateral side of the mortise. The distal articular surface of the tibia and the superior articular surface of the talus are parallel to each other and also parallel to the horizontal plane. The malleoli, however, are angled about 10° off the perpendicular plane; thus, they form an angle of about 80° with the horizontal articular surfaces of the tibia and the talus. These angles are important for weight bearing and mobility. Some injuries to the ankle mortise are severe, and every effort is made to maintain these angles during the treatment of the injuries. Figure 1-4 illustrates the ankle joint, and figure 1-5 illustrates the angles formed by the ankle mortise.

Exercises (203):

1. What three major bones make up the ankle joint?

2. On which bone is the medial malleolus?

3. On which bone is the lateral malleolus?

4. Why are the angles formed by the ankle mortise important?

5. What type of joint is the ankle?

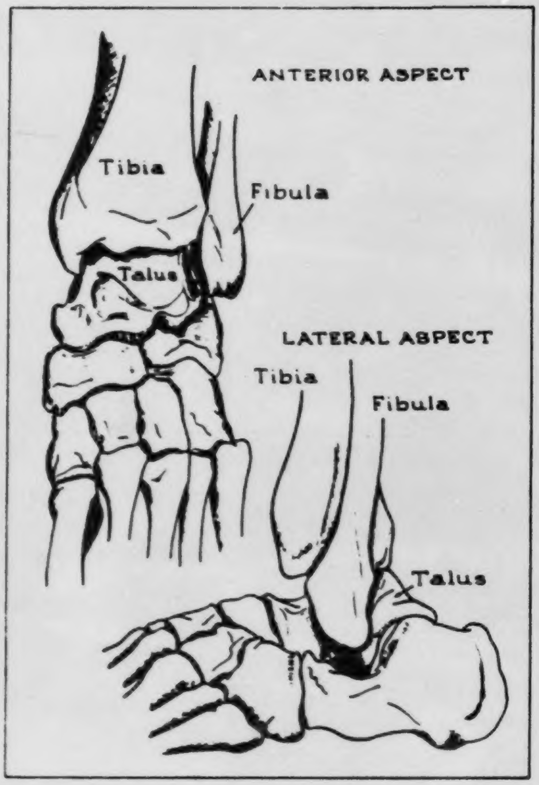


Figure 1 4. The ankle joint.

204. Name, locate, and describe the anatomical parts of the leg.

The Leg. The leg consists of two bones—the tibia and the fibula. We shall consider each separately, starting with the tibia. Using figure 1-6 as a reference will help you understand the descriptions.

The tibia. The larger of the two bones, commonly called the shin bone, is the tibia, located on the medial side of the leg. It has a shaft and two ends. The distal end of the tibia is much smaller than the proximal end. The inferior surface is smooth and articular, and the medial surface extends downward to form the medial malleolus.

The shaft of the tibia is somewhat triangular with three surfaces and three borders. The anterior crest, or border, which runs from just above the tibial tuberosity to the anterior margin of the medial malleolus, can be easily located by palpation. The medial border begins at the posterior portion of the medial condyle and extends downward to the posterior portion of the medial malleolus. The lateral border, often referred to as the interosseous crest, begins in front of the articular surface of the fibular head and extends down the bone. The medial surface is smooth and slightly convexed; the lateral surface is narrower than the medial. We can describe the posterior surface best if we divide it into thirds. The proximal third ends in the popliteal line. The middle third has a vertical ridge which starts at the popliteal line and gradually becomes indistinct as it descends. The distal third is smooth.

The major parts of the proximal tibia are the superior articular surface, the medial and lateral condyles, the intercondylar eminence, and the tibial tuberosity. The superior articular surface has two smooth articular surfaces which are separated by a groove. The smooth surface on the medial side is the superior surface of the medial condyle. The corresponding lateral surface is the superior articular surface of the lateral condyle. Both of these surfaces articulate with the condyles of the femur to form the knee joint. The grooves that separate these surfaces are the anterior and posterior intercondyloid fossae. Located in the middle of the intercondyloid fossa is the intercondyloid eminence or spine of the tibia. Just below the condyles, anteriorly, is the tibial tuberosity, which serves as the attachment place for the patellar ligament. The posterior surface of the proximal tibia contains the posterior intercondylid fossa. On the posterior surface of the medial condyle a deep groove runs transversely, and on the posterior surface of the lateral condyle is an articular surface for the head of the fibula.

The fibula. The fibula, the smaller of the two leg bones, is located on the lateral side of the leg, where it acts as a split for the tibia. It also serves as an attachment place for muscles and forms the lateral portion of the ankle joint. Like the tibia, it has a shaft and two ends. The distal end of the fibula is

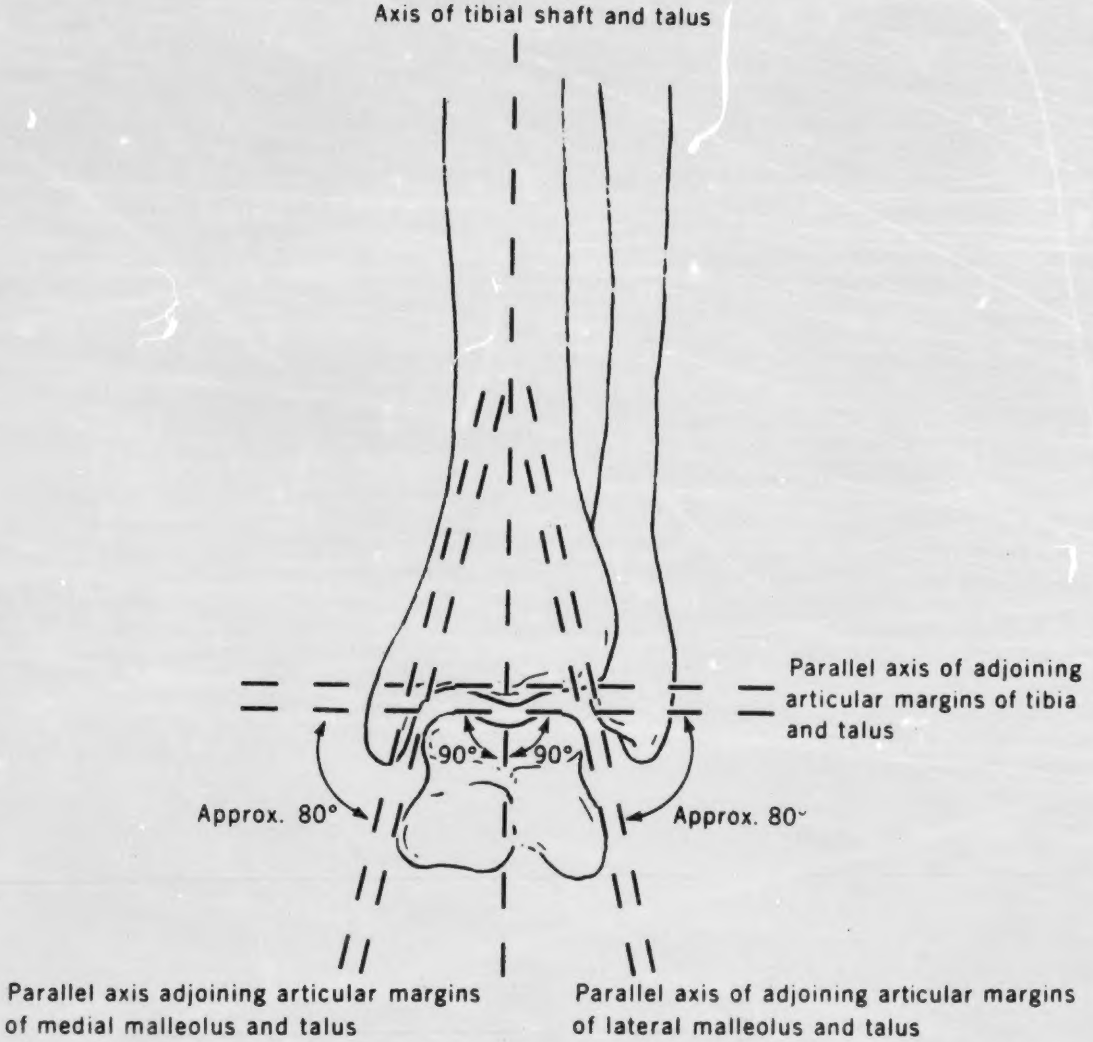

Axis of tibial shaft and talus
Parallel axis of adjoining articular margins of tibia and talus
90°
90°
Approx. 80°
Approx. 80°
Parallel axis adjoining articular margins of medial malleolus and talus
Parallel axis of adjoining articular margins of lateral malleolus and talus

Figure 1-5. The angles formed by the ankle mortise.

shaped somewhat like a pyramid and contains the lateral malleolus, which extends downward to complete the ankle mortise.

The shaft of the fibula has four borders and four surfaces. The anterior portion is divided into the anterolateral and anteromedial borders. The anterolateral border begins, proximally, in front of the fibular head and runs distally for about half the length of the bone. The anteromedial border, often called the interosseous crest, begins just below the fibular head and runs distally, parallel with the anterolateral border, for the proximal one-third of the bone. The posterior portion of the shaft is also divided into two borders, the posterolateral and the posteromedial. The posterolateral border begins just above the fibular styloid process and extends downward to the posterior portion of the lateral malleolus. The posteromedial border, often called the oblique line, begins at the medial side of the fibula and extends obliquely downward to the interosseous crest. The anterior surface is between the anteromedial and anterolateral borders. The posterior surface is between the posterolateral and posteromedial borders.

The upper expanded end of the fibular head articulates with the fibular articular surface of the lateral condyle of the tibia. However, the head of the fibula does not enter into the formation of the knee joint. The styloid process is that portion of the head that rises into a point above the articular surface.

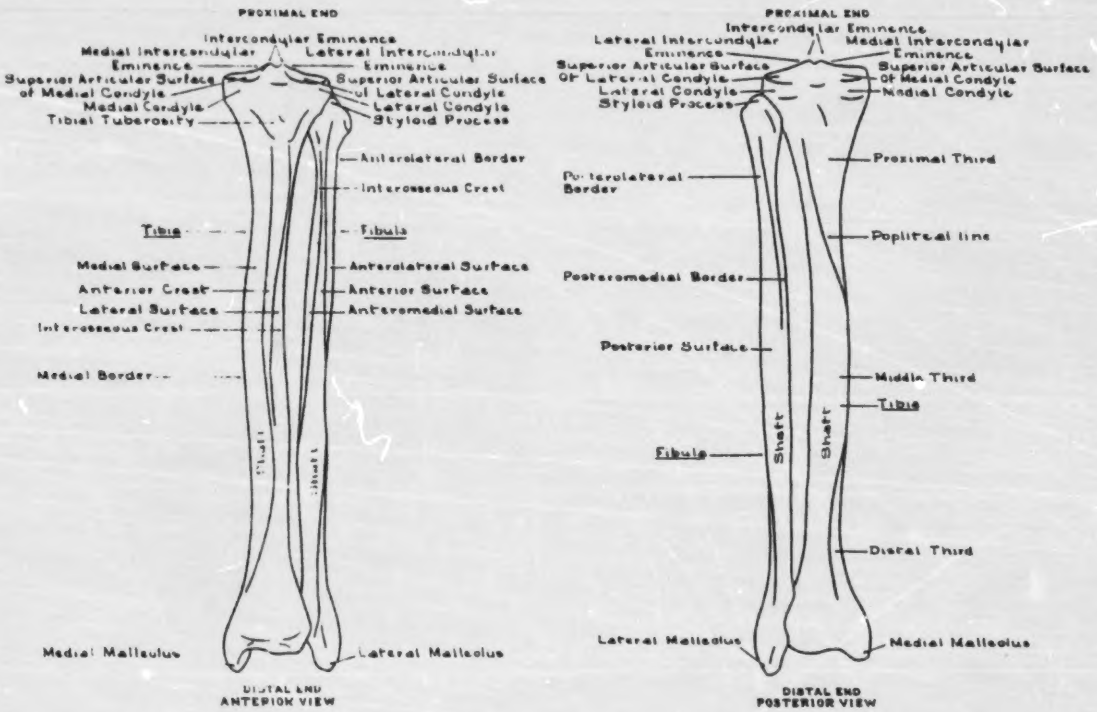


Figure 1-6. Bones of the leg.

Exercises (204):

1. What two bones comprise the leg?

2. Which leg bone is smallest?

3. What is the most distal portion of the tibia?

4. What is another name for the lateral border of the tibia?

5. Name the five major parts of the proximal tibia.

6. Where does the patellar ligament attach to the tibia?

7. What is the most distal portion of the fibula?

8 Is the head of the fibula on the proximal or distal end?

9. Where is the fibular styloid process located?

10. With what bone does the proximal portion of the fibular articulate?

205. Given a list of the parts of the knee and patella, match each with an appropriate descriptive statement or phrase.

The Knee and Patella. The knee is classified as a diarthrodial (hinge-type) joint. It consists, basically, of the proximal articular surface of the tibia, the distal articular surfaces of the femur, and the patella. The tibio-femoral articulations, though, are the parts most generally considered to be the "knee," while the patella is thought of as a separate entity. Therefore, we will first consider the knee as it is classically described, and then take up the patella.

The knee. We have already discussed the proximal articular surface of the tibia, so let's look at the femur. The distal articular surface of the femur consists of two large condyles, one medial and one lateral. They are separated by a large, tunnel-shaped notch, which is the intercondyloid fossa. The distal portions of these condyles are smooth and convex to enable articulation with the tibial condyles. Two rough elevations, one on the lateral side of the lateral condyle and the other on the medial side of the medial condyle, superior to the articular surfaces of both, form the lateral and medial epicondyles, respectively. On these eminences are attached the ligaments that, with those attached to the tibia, bind the joint.

The articulation formed by the femoral and tibial condyles are referred to as the tibio-femoral joints (see fig. 1-7).

The patella. The largest sesamoid bone in the body is situated in front of the knee joint—hence its common name, "kneecap." It is regarded as a sesamoid bone because it is developed within a tendon, has an ossification center presenting a tuberculated outline, and is comprised of dense, cancellous tissue. The patella is roughly diamond-shaped, with the narrow end (the apex) pointed down (see fig. 1-8). The superior aspect of the patella is round and much wider than the apex. The anterior surface is somewhat convex and is pitted by orifices, which permit the passage of nutrient vessels. The superior surface of the posterior patella is divided into two articular facets to permit articulation with the slightly V-shaped articular surface of the anterior portion of the distal femur (see fig. 1-7). The inferior surface is roughened for the attachment of the patellar ligament. The patella is superiorly housed in the expansion of the quadriceps femoris tendon (the large muscle group of the anterior thigh) and is inferiorly contained by the fiber of the patellar ligament. Both fibrous bands are continuous with each other, which accounts for the apparent "suspension" of the patella.

Exercises (205):

In the following exercises, match the knee or patellar part in column B with the appropriate statement in column A by placing the letter of the column B item in the correct space in column A. Each column B item may be used once or not at all.

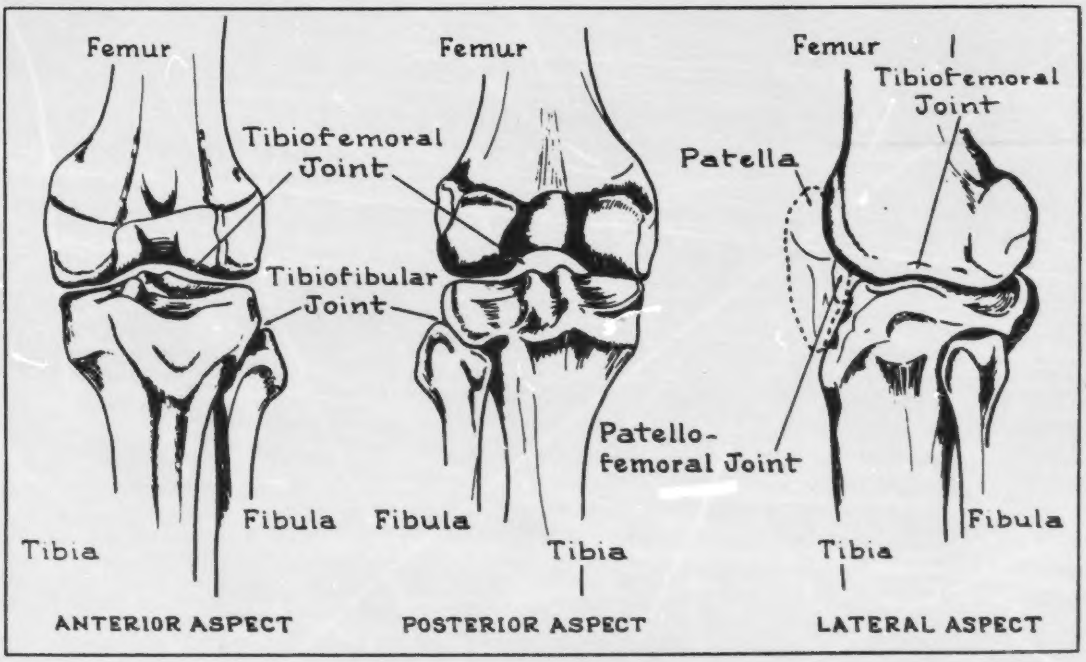
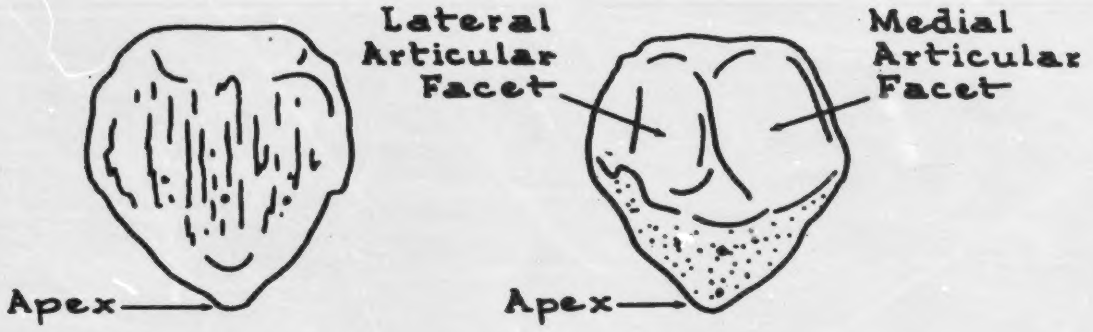


Figure 1-7. The knee joint.



ANTERIOR VIEW POSTERIOR VIEW

Figure 1-8. The patella.

Knee

Column A	*Column B*
___ 1. Between the femoral condyles.	a. Knee joint.
___ 2. Diarthrodial or hinge-type.	b. Intercondyloid fossa.
___ 3. Articulates with medial tibial condyle.	c. Femoral condyle.
___ 4. Elevation on lateral side of femoral condyle.	d. Condylar notch.
	e. Epicondyle.

Patella

___ 5. Inferior portion.	a. Articular facet.
___ 6. Joins with femur.	b. Anterior surface.
___ 7. Receives nutrients.	c. V-shaped articular surface.
	d. Apex.

206. Name, locate, and describe the anatomical parts of the femur.

The Femur. The femur, or thigh bone, extends from the knee joint to the hip joint. From the hip joint, the femur is directed somewhat medially and posteriorly so that, at the knee joint, it is near the center of gravity for the body. The femur, classified as a long bone, consists of a shaft and two ends. We have already discussed the distal end so let's turn to the shaft.

Shaft. The shaft is the long, rounded portion of the bone that extends from the intertrochanteric crest, proximally, to just above the epicondyles, distally. It is broader at the ends than in the middle and is widest at the distal end.

The posterior surface of the shaft contains the linea aspera, a rough prominence that occupies the middle one-third. Several less prominent ridges extend above it; below it, two prominent ridges extend downward to form the triangle on the distal portion of the posterior femoral shaft. The area within the triangle, deriving its name from the popliteal artery, is called the popliteal space.

Proximal end. This part consists of the head, the neck, the greater trochanter, and the lesser trochanter. The lesser trochanter is a small, rounded prominence on the lower portion of the femoral neck. The greater trochanter is a large, palpable, irregular prominence, which extends outward and slightly backward from the junction of the femoral neck with the femoral shaft. The intertrochanteric crest is the ridge of bone that extends obliquely downward from the greater trochanter to the lesser trochanter.

The neck is the constricted portion that unites the head with the body of the femur, and the head is the upper, rounded, expanded area that joins with the acetabulum to form the hip joint. Near the center of the head is an ovoid depression called the fovea capitis where the ligamentum teres attaches. The femur is shown in figure 1-9.

Exercises (206):

1. Name the rough area on the posterior middle third of the femur.

2. Give the configuration and location of the popliteal space.

3. On which side (anterior or posterior) of the femur is the intertrochanteric crest located?

4. In what direction(s) does the neck of the femur extend from the femoral body?

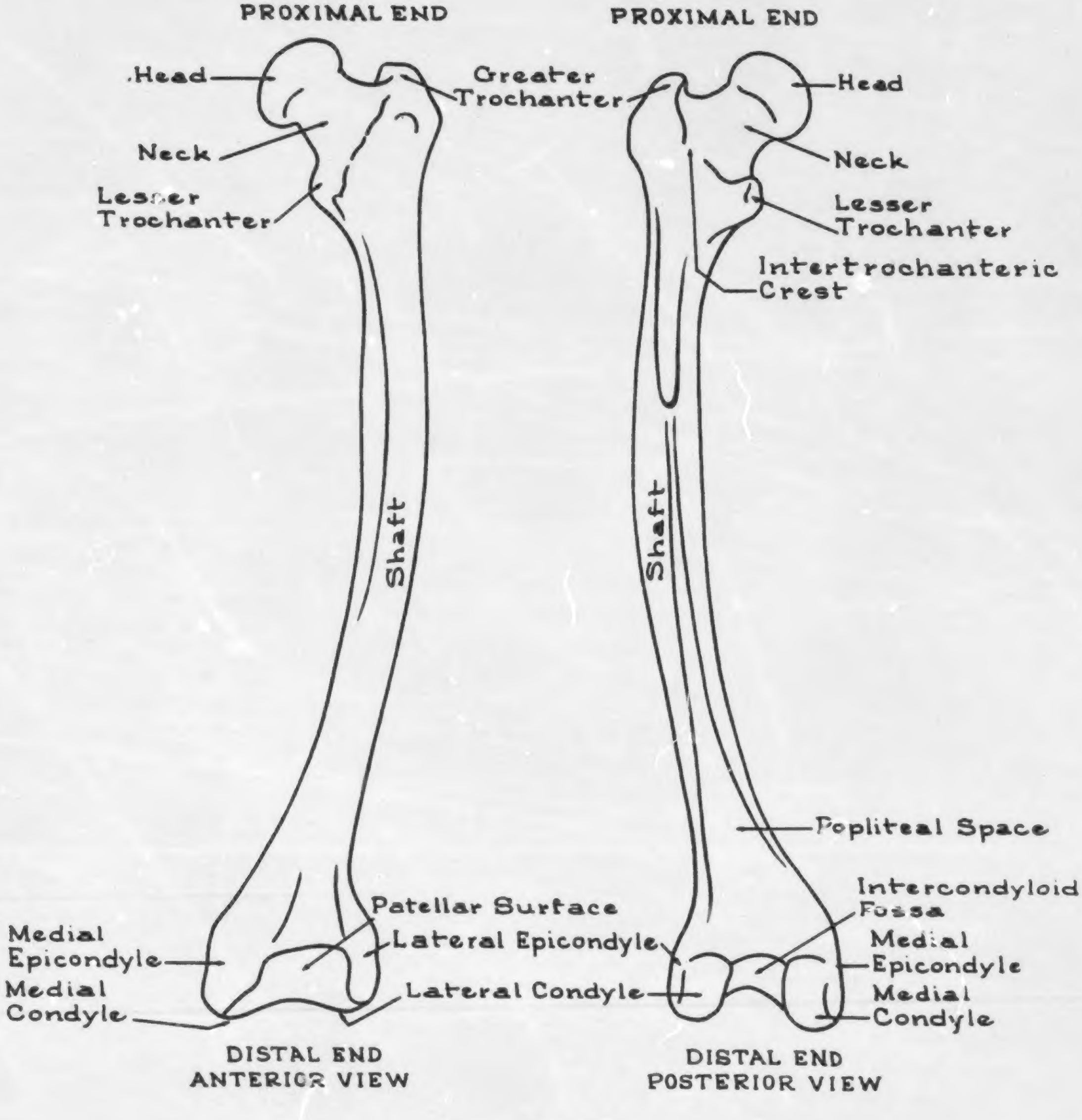


Figure 1-9. The femur.

5. What part of the femur helps form the hip joint?

6. Can the greater trochanter be palpated?

7. Name the depression on the center of the femoral head.

207. Given a list of statements pertaining to the innominate bones and pelvis, indicate which are true and which are false. If you indicate "false," you must explain your answer.

The Pelvic Girdle. The pelvic girdle consists of the two innominate, or hip, bones; the pelvis; the sacrum; and the coccyx. It also provides five articular surfaces consisting of both hips, both sacrioliac joints, and the symphysis pubis. We will investigate the bony parts first, and then the articulations.

The innominate bones. Each innominate bone, commonly called the hip bone, is formed by the fusion of what were once three separate bones. In the adult skeleton, the two innominate bones form the anterior and lateral walls of the pelvic girdle (see fig. 1-10).

The upper portion of the innominate bone is the ilium. Its major components and landmarks are: the body, the ala, the iliac fossa, the articular surface, the iliac crest, the anterosuperior iliac spine (ASIS), the anteroinferior iliac spine (AIIS), the posterosuperior iliac spine (PSIS), the posteroinferior iliac spine (PIIS), and the greater sciatic notch.

a. The body of the ilium is the thick part of the bone just above the acetabulum.

b. The ala (from a Latin word meaning "wing") is the winglike portion of the ilium.

c. The iliac fossa is a large area on the inside surface of the ala—bounded by the iliac crest superiorly and by the arcuate line inferiorly.

d. The articular surface, often called the auricular surface because of its "ear" shape, is that part of the internal alar surface that articulates with the corresponding articular surface of the sacrum to form the sacrioliac joint.

e. The crest of the ilium (iliac crest) is the upper, curved border of the ala.

f. The easily palpable anterosuperior iliac spine is the bony prominence located where the iliac crest joins the rest of the anterior iliac border.

g. The anteroinferior iliac spine is a bony prominence located on the anterior border at a level about 1 inch lower than the anterosuperior iliac spine.

h. The posterosuperior iliac spine is the bony prominence located where the iliac crest joins the rest of the posterior border.

i. The posteroinferior iliac spine is the bony prominence directly below the posterosuperior iliac spine on the posterior border.

j. The greater sciatic notch is a large notch just below the posterior inferior iliac spine.

k. The ilium forms part of the acetabulum.

The ischium is the lower posterior part of the innominate bone. Its major parts and landmarks are the body, the ischial spine, the lesser sciatic notch, the superior ramus, the ischial tuberosity, and the inferior ramus.

a. The body of the ischium is the thick part of the bone directly behind and below the acetabulum. It also forms part of the acetabulum.

b. The ischial spine is a pointed prominence extending backward and medially from the posterior surface.

c. The lesser sciatic notch is a small notch just below the ischial spine.

d. The ramus is that part of the bone that descends from the ischial body.

e. The ischial tuberosity is the large expanded part located at the posterior surface of the ramus.

The pubis forms the lower anterior part of the innominate bone. Its major parts and landmarks are the body, the superior ramus, the pubic tubercle, the iliopectineal eminence, the obturator crest, and the inferior ramus.

a. The body makes part of the anterior portion of the acetabulum.

b. The superior ramus is somewhat triangular shaped and extends upward and backward from the pubic body to the acetabulum.

c. The pubic tubercle, often called the pubic spine, is a small prominence located on the upper border of the pubic body.

d. The iliopectineal eminence, sometimes called the iliopubic eminence, is a rough eminence marking the fusion site of the ilium and the pubis.

e. The obturator crest is the lower border of the superior ramus and extends from the pubic tubercle to the lower margin of the iliopectineal eminence in front of the acetabular notch. It is part of the obturator foramen.

f. The inferior ramus is the part of the bone that extends downward from the pubic body to join the ramus of the ischium.

g. The obturator foramen is a large hole between the ischium and the pubic bones.

h. The pubic arch is the arch formed by the ramus of the ischium and the inferior ramus of the pubis as they extend upward and join at the inferior aspect of the symphysis pubis. It is usually a broad, rounded curve in the female and a much smaller, narrower, inverted, V-shaped angle in the male.

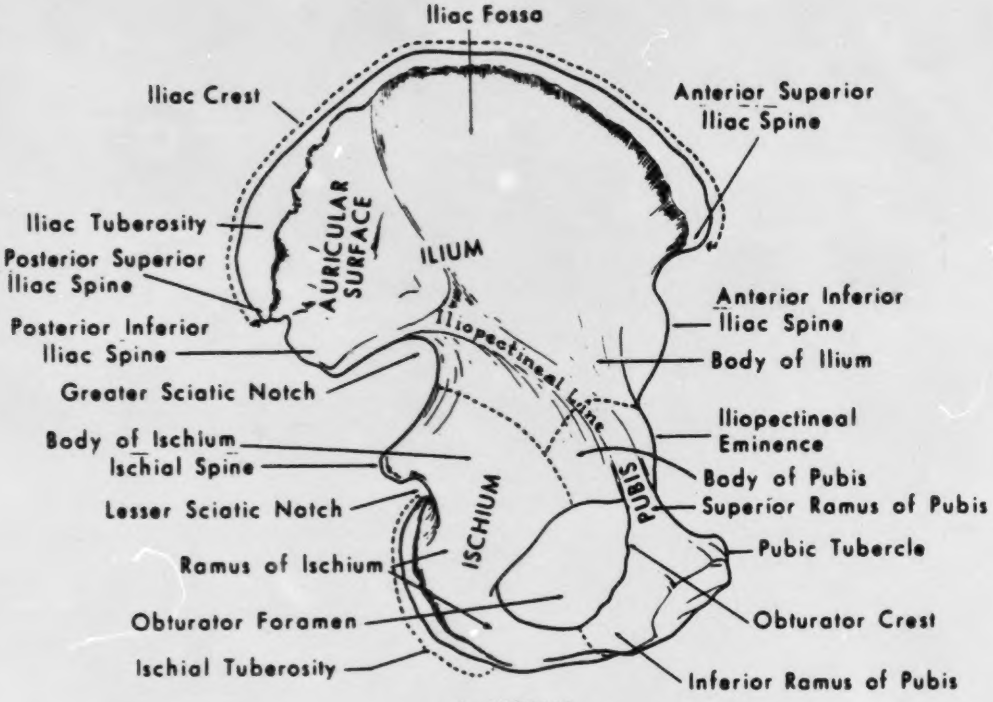
i. The acetabulum is the cup-shaped depression that receives the head of the femur in forming the hip joint.

The pelvis. The pelvis is formed by the innominate bones, the sacrum, and the coccyx. The oval, bony ridge on the inner pelvic surface is the pelvic brim. It begins at the superior border of the symphysis publis and extends upward on both sides along the superior rami of the pubis and the iliopectineal lines until it meets at the center of the sacral promontory.

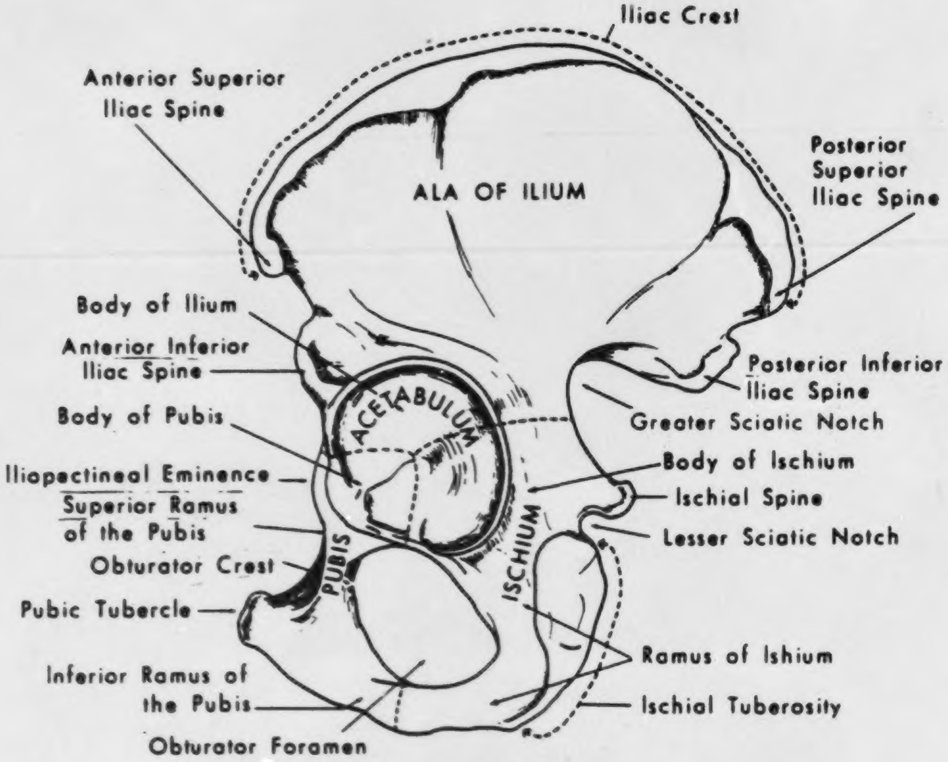
The false pelvis, often called the major or greater pelvis, is the part of the lower abdomen bounded by the pelvic brim and by the alae of the ilia on the sides. The true pelvis, also called the minor or lesser pelvis, is bounded by the pelvic brim above, the sacrum and coccyx behind, and the symphysis pubis in front. These structures form the pelvic inlet and outlet. (See fig. 1-11.)

Exercises (207)

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.



A. MEDIAL



B. LATERAL

Figure 1-10. The innominate bone.

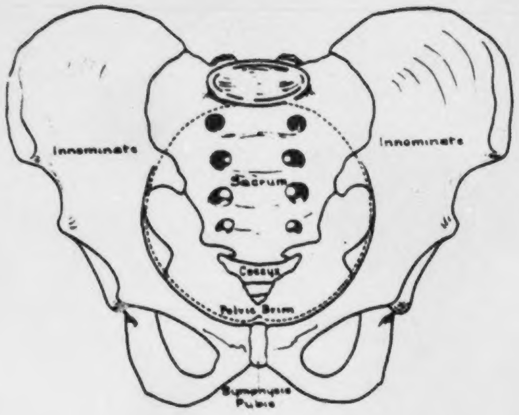


Figure 1-11. The pelvis.

T F 1. The three bones that comprise the innominate bones are the ilium, the pubis, and the ischium.

T F 2. The iliac crest extends from the ASIS to the PIIS.

T F 3. The sacrum articulates with a portion of the iliac wing.

T F 4. The PSIS is located on the ilium.

T F 5. The ASIS is easily palpable.

T F 6. The greater and lesser sciatic notches are located on the ilium.

T F 7. The ischial spine is located between the greater and lesser sciatic notches.

T F 8. Part of the ilium, ischium, and pubis make up the acetabulum.

T F 9. There are two obturator foramina in the innominate bones.

T F 10. The inferior ramus of the pubis and the body of the ischium form the pubic arch.

T F 11. The pubic arch in the male is shaped like an inverted V.

T F 12. Four major bones form the pelvis.

T F 13. The true pelvis is separated from the false pelvis by the pelvic brim.

T F 14. The posterior margin of the false pelvis is formed by the sacrum and coccyx.

208. Describe the anatomy of the sacrum and coccyx by giving the name, number, location, and description of the various parts.

The sacrum. The sacrum is formed from five atypical individual vertebrae, which, until about age 18, are separated by cartilage. The sacrum resembles a triangular wedge and is located between the two innominate bones at the lower part of the vertebral column directly below the lumbar vertebrae. In this location, it forms part of the posterior limit of the pelvic cavity. Its main components and landmarks are its anterior surface, posterior surface, lateral surfaces, base, apex, and sacral canal. We will consider the anterior surface first.

a. The anterior surface is concave and has four transverse lines representing the original separation of the sacral vertebrae. Between these lines are the bodies of the vertebrae. The first, or top, vertebra is the largest; the others become smaller as the sacrum descends. On the sides of the transverse lines are the anterior sacral foramina, which provide passage for several nerves and arteries.

b. The posterior surface is convex and has a prominent ridge, the midsacral crest, descending from its midportion. The first sacral vertebra has superior articular facets with smooth articular surfaces that extend posteromedially and articulate with the fifth lumbar vertebra. The inferior articular facets of the fifth sacral vertebra are round and extend downward to articulate with the articular processes of the first coccygeal vertebra. Laterally, from the articular crest, are the posterior sacral foramina.

c. The lateral surfaces, in regard to the posterior portion, have bilateral ear-shaped, articular surfaces, which join with the ilia to form the sacroiliac joints. As the lateral surfaces descend, they become narrower towards the extreme tip of the lateral surface or the inferolateral angle.

d. The base of the sacrum is formed by the superior surface of the first sacral vertebra and has three parts: a middle part and two lateral surfaces. The middle part consists of an oval articular surface on the body of the first vertebra. This area has an important bony landmark called the promontory. The two lateral surfaces of the sacral base, often called the ala of the sacrum, are represented by the fused costal and transverse processes.

e. The apex is the inferior part of the sacrum that joins with the coccyx.

f. The sacral canal is located near the posterior part of the sacrum and extends from the first to the fifth vertebra. It is formed by the posterior aspect of the sacral vertebral bodies and the fusion of the laminae and spinous processes (see fig. 1-12).

The coccyx. The coccyx, commonly called the tailbone, is the last segment of the vertebrae in the vertebral column and is generally formed by the fusions of four atypical vertebrae. It has an anterior surface, a posterior surface, a base, and an apex, shown in figure 1-13.

a. The anterior surface resembles the anterior surface of the sacrum because it is concave and has three transverse lines that mark the former separations between the coccygeal vertebrae.

b. The posterior surface of the coccyx resembles, in miniature, the posterior surface of the sacrum. Extending upward from the coccygeal base are the coccygeal cornua, which join the sacral cornua of the sacral apex.

c. The base is the superior surface of the first coccygeal vertebra and joins with the apex of the sacrum.

d. The apex is the extreme distal tip of the last coccygeal vertebra.

Exercises (208):

Answer the following questions or fill in the blanks as appropriate.

1. How many sacral vertebrae are there?

2. Which sacral vertebra is the largest? The smallest?

3. The midsacral crest is located on the _____ side of the sacrum.

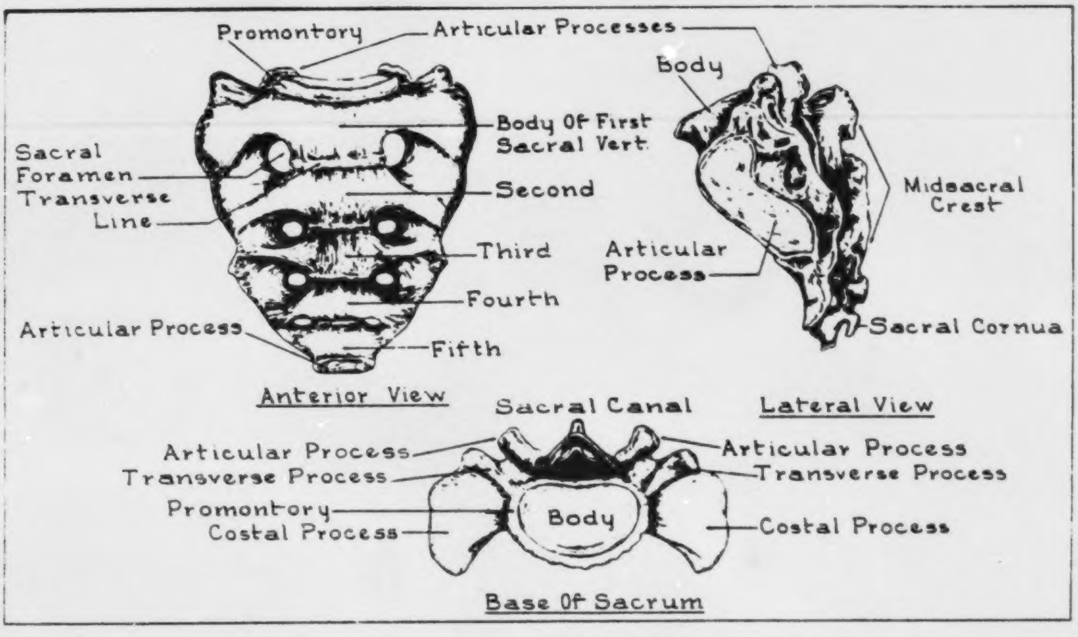


Figure 1-12. The sacrum.

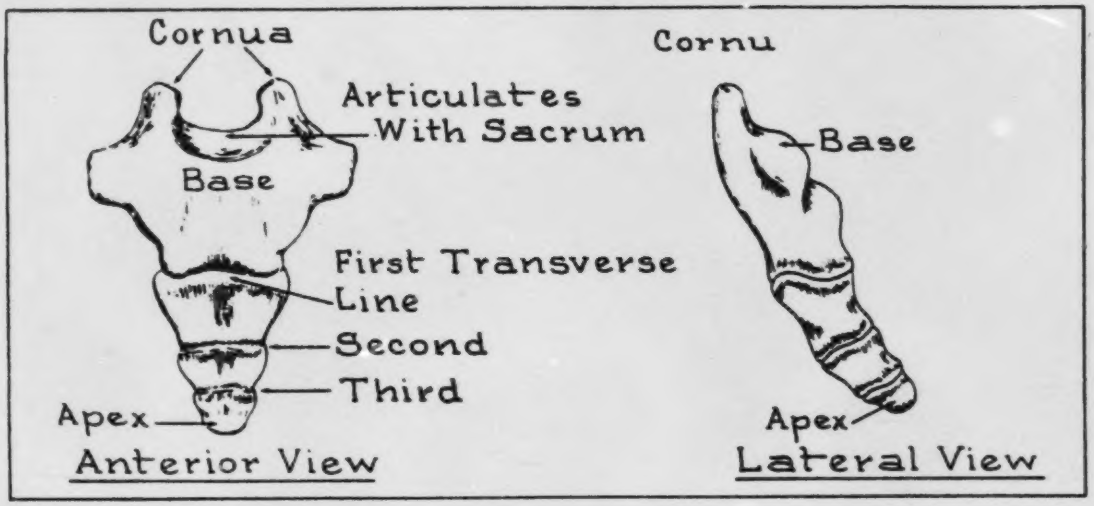


Figure 1-13. The coccyx.

4. With what vertebra does the superior articular facets of the sacrum articulate?

5. With what vertebra does the inferior articular facets of the fifth sacral vertebra articulate?

6. The lateral surfaces of the sacrum articulate with the _____ to form the _________.

7. What is the sacral promontory and where is it located?

8. Where is the sacral canal located with respect to the sacral body?

9. How many coccygeal vertebra are there?

10. What are the transverse lines of the coccyx?

11. What are the two bony projections that extend superiorly from the coccygeal base?

12. The superior portion of the first coccygeal vertebra is called the _____ and the inferior tip of the fourth coccygeal vertebra is called the _________.

1-3. The Upper Extremity

The upper extremity includes the fingers and the hand, the wrist, the forearm, the elbow, the humerus, and the shoulder girdle.

209. Characterize the anatomy of the fingers, hand, and wrist by giving the name, number, location, and description of the various parts.

The Fingers and the Hand. Nineteen bones, when united, form the fingers and hand. They are divided into two groups—the phalanges, which form the fingers, and the metacarpals, which form the palm. We will investigate the phalanges first.

The phalanges. Each digit has three phalanges, except the thumb, which has two. Each phalanx has a body, a head or distal end, and a base or proximal end. The phalanges are not named but are identified by their location and number, counted from the thumb to the little finger (see fig. 1-14). For example, the phalanx of the thumb nearest the palm is the proximal phalanx of the first digit; the middle phalanx of the middle finger is the middle phalanx, third digit; and the distal phalanx of the little finger is the distal phalanx, fifth digit. The distal phalanges are distinguished by their small size and by the ungual tuberosity (or tuft) at their distal ends.

The metacarpals. The five metacarpals are the longer bones that form the palm of the hand. Each has a body, a head or distal end, and a base or proximal end. The metacarpals do not have names, but they are identified by the numbers 1 through 5, counted from the thumb to the little finger. Again, see figure 1-14. The first metacarpal is shorter and wider than the others.

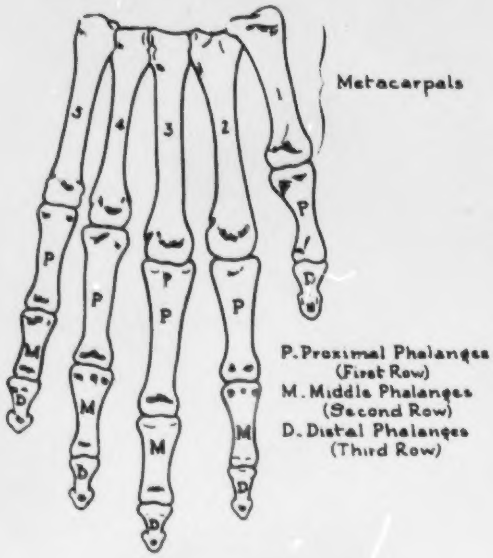

Metacarpals
5
4
3
2
1
P
M
D
P. Proximal Phalanges (First Row)
M. Middle Phalanges (Second Row)
D. Distal Phalanges (Third Row)

Figure 1-14. The fingers and hand.

The Wrist. The wrist, or carpus, is arranged in distal and proximal rows (see fig. 1-15). The carpals, classified as short bones, are cube-shaped and are identified by name from the radial or thumb side to the medial or ulnar side. Most of them are referred to by more than one name. The outstanding characteristics of the carpal bones are: (1) each one except the pisiform has six surfaces; (2) the superior surfaces are somewhat convex, the inferior surfaces are concave; and (3) the outer surfaces are either articular surfaces or roughened surfaces to provide attachment for ligaments.

Greater multangular (trapezium). This carpal is on the lateral or radial aspect of the distal row of carpal bones. It has a small tubercle projecting from its anterior surface.

Lesser multangular (trapezoid). This is the smallest bone of the distal row. Its shape resembles that of a wedge.

Capitate (os magnum). This is the largest carpal bone. It forms the center of the wrist.

Hamate (unciform). This carpal is located on the medial, or ulnar, side of the distal row. It is somewhat wedge-shaped and has a hooklike process, which rises from its anterior surface.

Navicular (scaphoid). This bone is the largest carpal in the proximal row. It is located on the lateral aspect of this row.

Lunate (semilunar). This carpal is located in the center of the proximal row between the navicular and triangular.

Triangular (triquetral or cuneiform). This bone is located on the medial, or ulnar, side of the proximal row. It is distinguished by its triangular shape.

Pisiform. This is the smallest carpal bone. It lies anterior to the triangular.

Exercises (209):

1. What are the three parts of a phalanx?

2. Which digit(s) has no middle phalanx?

3. How many phalanges are there in the hand?

4. How should the center bone of the ring finger be identified?

5. On which end of a metacarpal bone is the head? The base?

6. Which metacarpal joins the ring finger?

7. On which phalanges is the ungual tuberosity?

8. How many carpal bones are there in one hand?

9. Which bones make up the distal carpal row?

10. Which bones make up the proximal carpal row?

11. Which is the smallest carpal bone?

12. Which is the largest carpal bone?

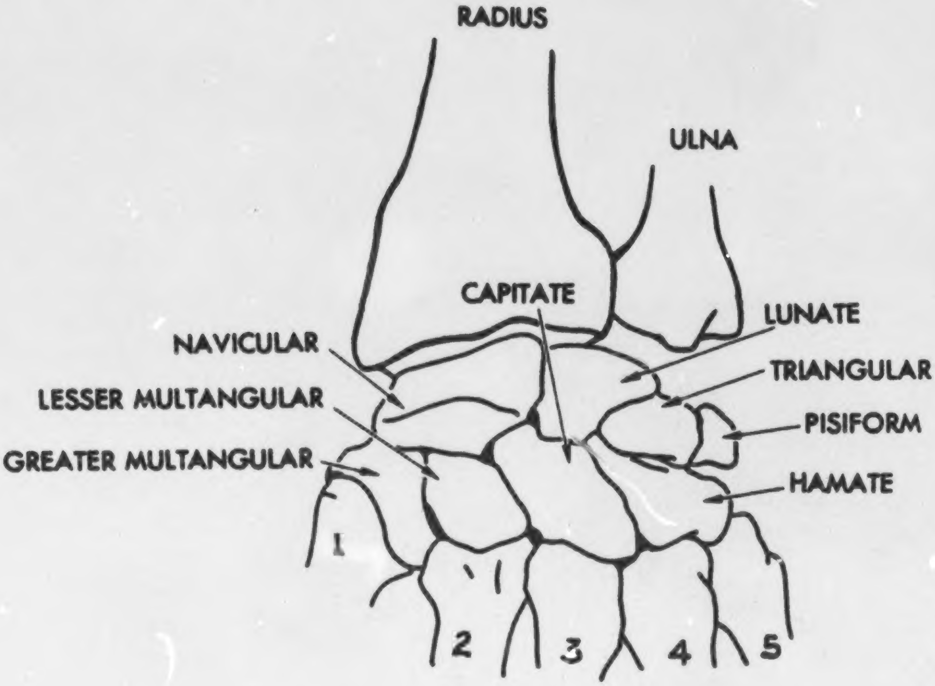


Figure 1-15. The wrist.

210. Given a list of the parts and descriptions of the two bones of the forearm, match each with the appropriate bone.

The Forearm. The forearm extends from the wrist to the elbow and consists of two bones, the ulna and the radius. We will consider the ulna first. Coordinate your reading of this material by locating the forearm features in figure 1-16.

The ulna. The ulna, located on the medial side of the forearm, is classified as a long bone with a shaft and both distal and proximal ends. It tapers from the proximal to the distal ends, and the distal end bends laterally to form a slight bow. The distal end is much smaller than the proximal end and has two outstanding landmarks—the head and the styloid process. The shaft, somewhat rounded at its proximal end, becomes increasingly smaller toward its distal end. A rough wedge on the lateral aspect is the interosseous border, to which the interosseous membrane is attached. On the proximal end are these prominent landmarks: the radial notch, the oblong depression on the lateral side of the coronoid process; the coronoid process, a large, pyramidal projection from the anterior surface; the semilunar notch, the arched depression extending between the olecranon and the coronoid processes; and the olecranon process, a large, curved eminence.

The radius. The radius, also shown in figure 1-16, is the lateral bone of the forearm and, like the ulna, is a long bone with a shaft and both distal and proximal ends. In contrast to the ulna, it tapers from the distal to the proximal end. Prominent landmarks on the distal end are the ulnar notch—a small depression on the medial side—and the styloid process—a conical projection of bone on the lateral side. The shaft becomes larger as it approaches the distal end and has a slight lateral curvature. The interosseous crest forms the sharp medial side of the shaft. The proximal end consists of the radial tuberosity—located on the medial side of the neck; the neck—the round, smooth, constricted part distal to the head; and the head—a cup-shaped, disclike structure adapted for articulation with the capitulum of the humerus.

Exercises (210):

Match the forearm bone in column B with related information in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once.

Column A

___ 1. Larger distal end.
___ 2. Coronoid process.
___ 3. Radial notch.
___ 4. Semilunar notch.
___ 5. Radial tuberosity.
___ 6. Olecranon process.
___ 7. Medial bone.

Column B

a. Radius.
b. Ulna.

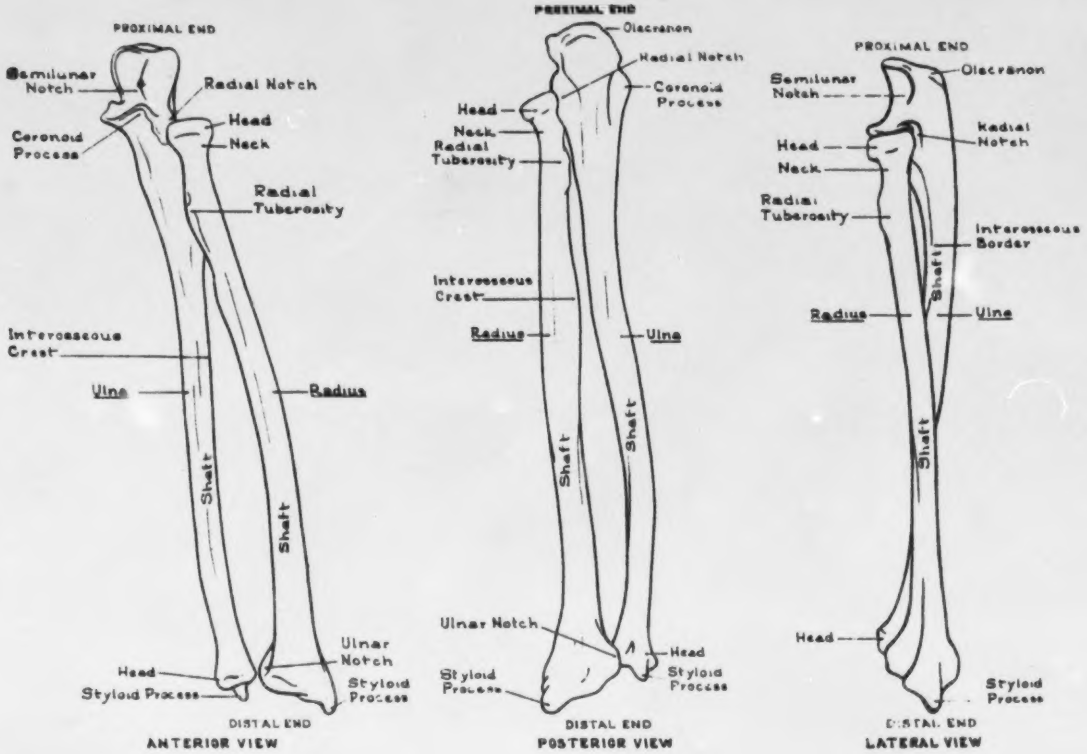


Figure 1-16. The forearm.

211. Given a list of statements pertaining to the elbow, indicate which are true and which are false. If you indicate "false," you must explain your answer.

The Elbow. The elbow is formed by the articulation of the proximal portions of the ulna and radius and the distal portion of the humerus. Since we have already discussed the proximal radius and ulna, let's look at the distal humerus.

The distal portion of the humerus. The flared, distal end of the humerus presents five surfaces—lateral, medial, anterior, posterior, and inferior—which in one way or another help form the elbow. The anteroinferior surface is comprised of the articular surface. This surface is divided into two parts by a slight ridge. The medial aspect is formed by the trochlea, which is a deep depression between two well-marked borders. The lateral portion consists of the capitulum—a smooth, rounded eminence, marked by a slight groove on its medial aspect. Directly above and posterior to the capitulum is the radial fossa, a small, smooth depression. Medial to this fossa and directly above and behind the trochlea is the coronoid fossa. The medial aspect of the distal humerus is formed by the medial epicondyle. This is a tubercular eminence, larger and more prominent than its lateral counterpart, to which are attached various ligaments, tendons, and muscles. The lateral epicondyle, though it serves the same purpose, is smaller. The posterior portion of the distal humerus is identified by a deep depression—the olecranon fossa—just above the posterior aspect of the trochlea. This fossa, the trochlea, the capitulum, and both coronoid and radial fossae are covered by a synovial membrane. They form the superior aspect of the articular capsule of the elbow (see fig. 1-17).

The elbow joint. The elbow is formed by the combined articulation of the ulna and radius and the articulation of both of these bones with the humerus. The head of the radius articulates with the radial notch on the lateral aspect of the coronoid process. An articulation is also formed by the capitulum and the fovea, on the superior surface of the radial head. The trochlea articulates with the semilunar notch of the ulna. In extreme hyperflexion, the medial margin of the radial head is received by the radial fossa on the anterior surface of the distal humerus and the tip of the coronoid process is received by the coronoid fossa. In extension, the olecranon process is received by the olecranon fossa. Both epicondyles give attachment to the ligaments which bind the joint together (see fig. 1-18).

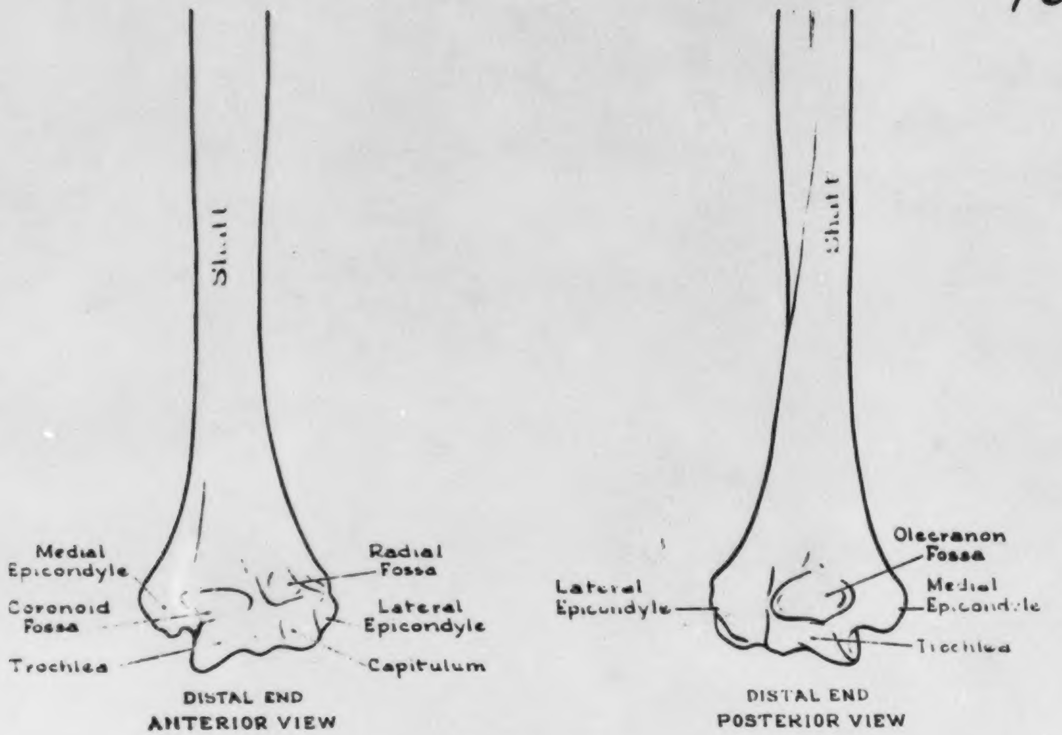


Figure 1-17. The distal end of the humerus.

Exercises (211):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. The olecranon fossa is located on the anterior side of the humerus.

T F 2. The coronoid fossa is located on the anterior side of the humerus.

T F 3. The radial fossa is located on the medial side of the humerus.

T F 4. The lateral epicondyle is more prominent than the medial.

T F 5. The deep depression on the posterior surface of the humerus is the trochlea.

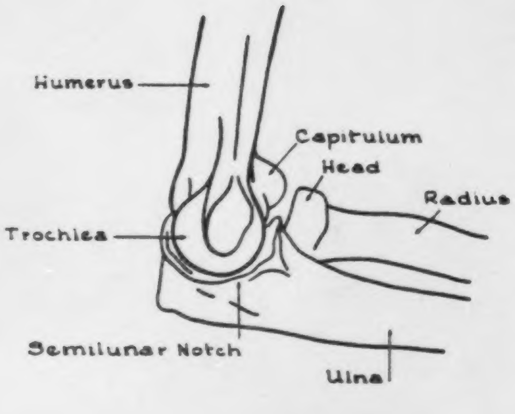


Figure 1-18. The elbow.

T F 6. The radius articulates with the radial notch and the capitulum.

T F 7. The ulnar semilunar notch articulates with the olecranon fossa.

T F 8. The olecranon process is received by the olecranon fossa when the elbow joint is flexed.

212. Name the parts of the proximal humerus and give a brief description of each.

The Humerus. The humerus is the bone that extends distally from the shoulder joint to the elbow joint. It is the largest bone of the upper extremity and is classified as a long bone. Since we have previously discussed the distal humerus, we will begin with the shaft (see fig. 1-19).

Shaft. The shaft is the part of the bone that extends from the tuberosities to the olecranon and coronoid fossae. It is round at the proximal end and becomes flattened toward the distal end.

Proximal end. There are several elements in the proximal end of the humerus. The surgical neck is

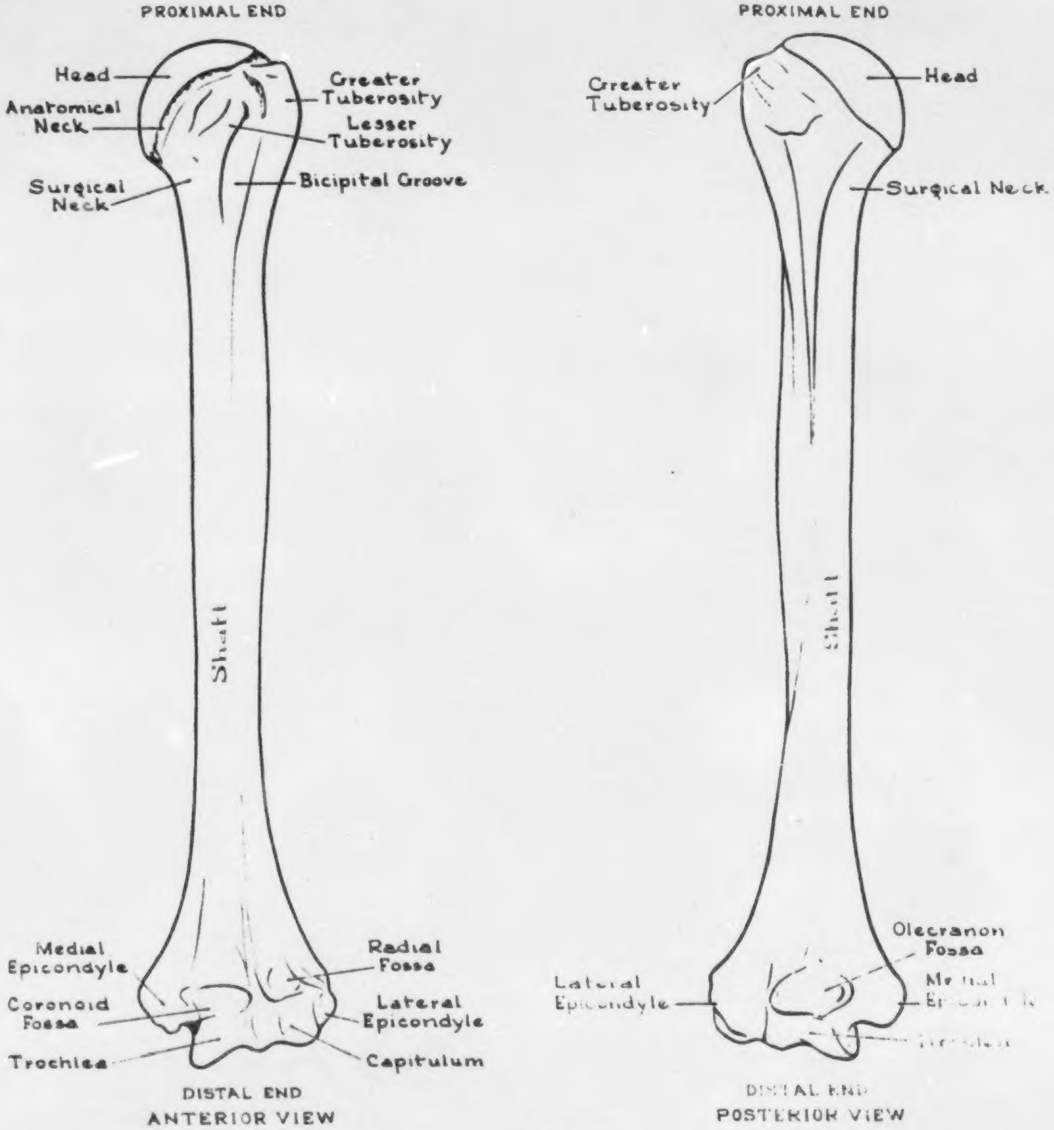


Figure 1-19. The humerus.

the constricted portion of the humerus below the tuberosities; it comprises the proximal one-third of the shaft. The lesser tuberosity is a bony eminence located on the anterior surface of the proximal humerus just below the anatomical neck. The greater tuberosity is a rounded eminence on the lateral side of the proximal end just below the anatomical neck. It is an insertion place for the spinatus muscles. The bicipital groove is a deep furrow located on the anterior surface of the proximal humerus between the greater and lesser tuberosities. It runs distally in a slightly inferomedial direction, ending about one-third the length of the humerus, and is deeper at the proximal end than at the distal end. The anatomical neck is located between the greater and lesser tuberosities and the head. It connects the head with the shaft. The head is the uppermost portion of the humerus and sits obliquely on the proximal medial surface of the bone and is directed slightly backward.

Exercises (212):

In exercises 1 through 6 that follow, name the parts of the proximal humerus and give a brief description of each part. For example: the shaft—the part of the humerus that extends from the tuberosities to the olecranon and coronoid fossae.

1.

2.

3.

4.

5.

6.

213. Describe the anatomy of the clavicle and scapula.

The Shoulder Girdle. The shoulder girdle consists of two bones—the clavicle and the scapula. We will examine the clavicle, then the scapula, and finally the joint itself.

The clavicle. The clavicle, commonly called the collarbone, is a long bone whose shape resembles the Old English letter "S." It is located on the superior anterolateral portion of the thorax and extends horizontally. As you can see in figure 1-20, important landmarks of the clavicle are:

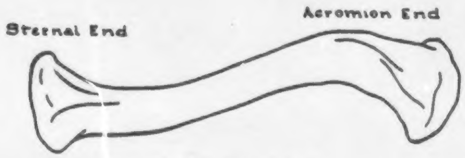
- *The sternal end*—medial portion.
- *The acromial end*—the lateral part.
- *The coracoid tuberosity*—a rough eminence located on the posterior border of the lateral third of the bone.
- *The costal tuberosity*—a rough area located on the medial part of the medial one-third.

The scapula. The scapula, or shoulder blade, is a flat, triangular-shaped bone located on the posterior superolateral part of the thorax, extending inferiorly from the level of the second rib to about the level of the eighth rib. It forms the posterior part of the shoulder girdle and is connected to the chest walls by muscles only. It has two surfaces, three borders, three angles, and the following other components that are important in radiographic studies: the subscapular fossa, the spine of the scapula, the supraspinatus fossa, the infraspinatus fossa, the acromion process, the neck of the scapula, the glenoid fossa, and the coracoid process. These parts can be seen in figure 1-21.

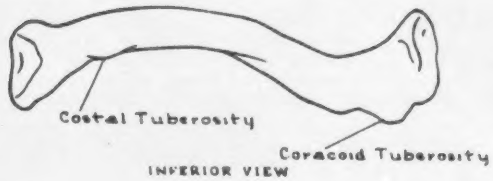
The anterior surface of the scapula is concave; the concavity is called the subscapular fossa. The medial two-thirds of the anterior surface contains ridges, which begin at the vertebral border and extend superolaterally.

The posterior surface of the scapula is slightly arched. The spine of the scapula is a projecting plate of bone running superolaterally from the vertebral border. The area above the spine is the supraspinatus fossa; the area below is the infraspinatus fossa.

The scapula has three borders—the superior, the axillary, and the vertebral. The shortest and



SUPERIOR VIEW



INFERIOR VIEW

Figure 1 20. The clavicle.

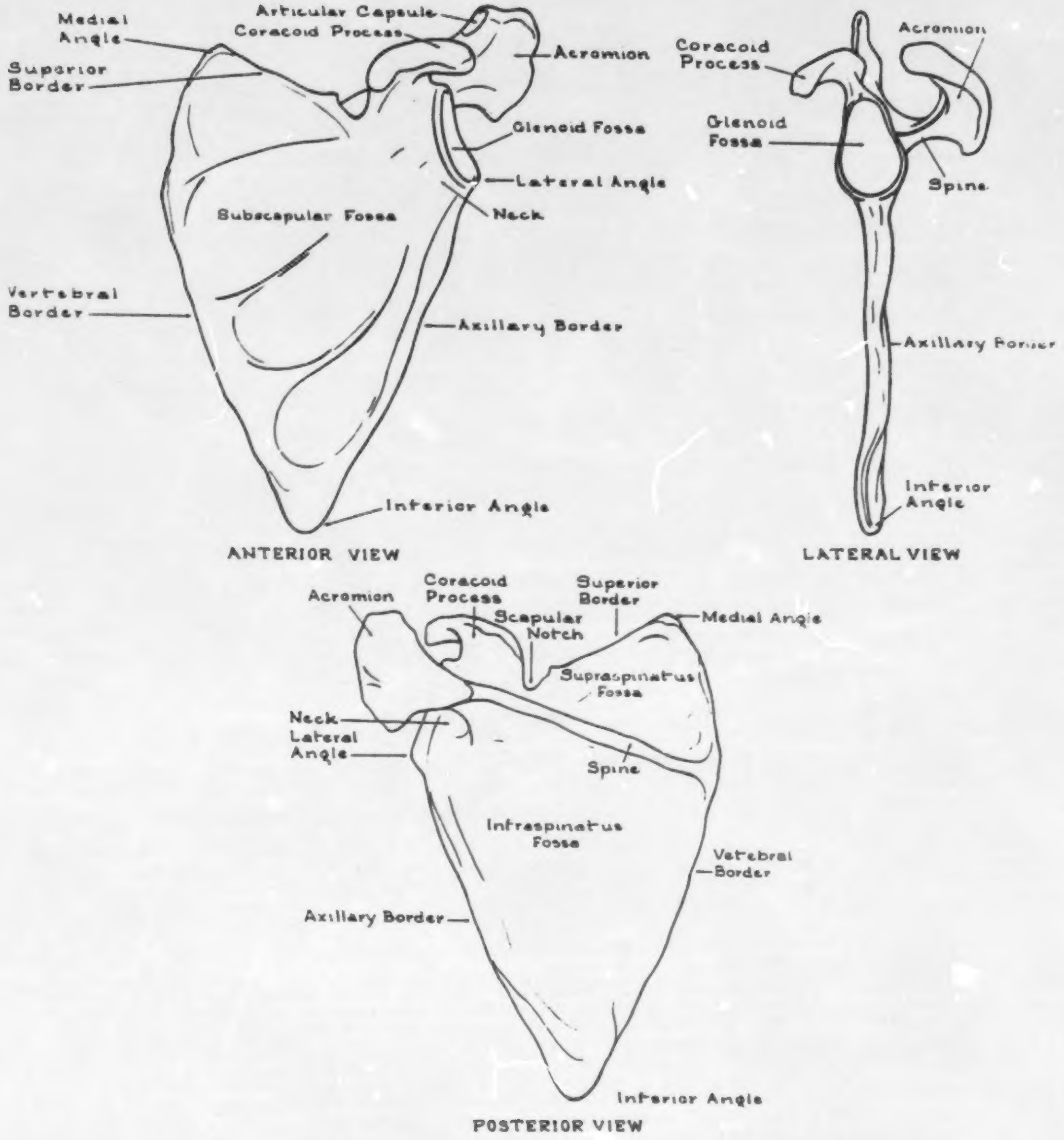


Figure 1-21. The scapula.

thinnest is the superior, which is concave and extends from the medial angle to the coracoid base. At the base of the coracoid process, where the superior border meets the base, is the scapular notch.

The three angles frequently used as anatomical landmarks are the medial angle, the lateral angle, and the inferior angle. The medial angle is formed where the superior and vertebral borders intersect. The lateral angle is located laterally on the superior part of the axillary border. The lateral angle contains the glenoid fossa.

The acromion process is a triangular projection which, at the lateral end of the scapular spine, extends slightly anteriorly and over the shoulder joint.

The glenoid fossa is the oval depression on the outer part of the scapular head at the lateral angle. It forms one-half of the shoulder joint.

The coracoid process resembles a bent forefinger and extends anterolaterally from the neck of the scapula.

The shoulder joints. There are two joints in the shoulder that are of particular interest to you. The glenohumeral or shoulder joint (an enarthrodial or ball and socket type of joint) and the acromioclavicular (A.C.) joint. The shoulder joint is formed by the head of the humerus and the glenoid fossa of the scapula. The A.C. joint is formed by the acromion process of the scapula and the distal end of the clavicle. See figure 1-22.

Exercises (213):

1. What is the medial portion of the clavicle? The lateral portion?

2. Give the names of the two tuberosities of the clavicle.

3. Name the concavity of the anterior surface of the scapula.

4. What is the scapular spine and where is it located?

5. Name the two areas directly above and below the scapular spine.

6. On which scapular border is the scapular notch?

7. Which scapular angle is formed by the junction of the vertebral and axillary borders?

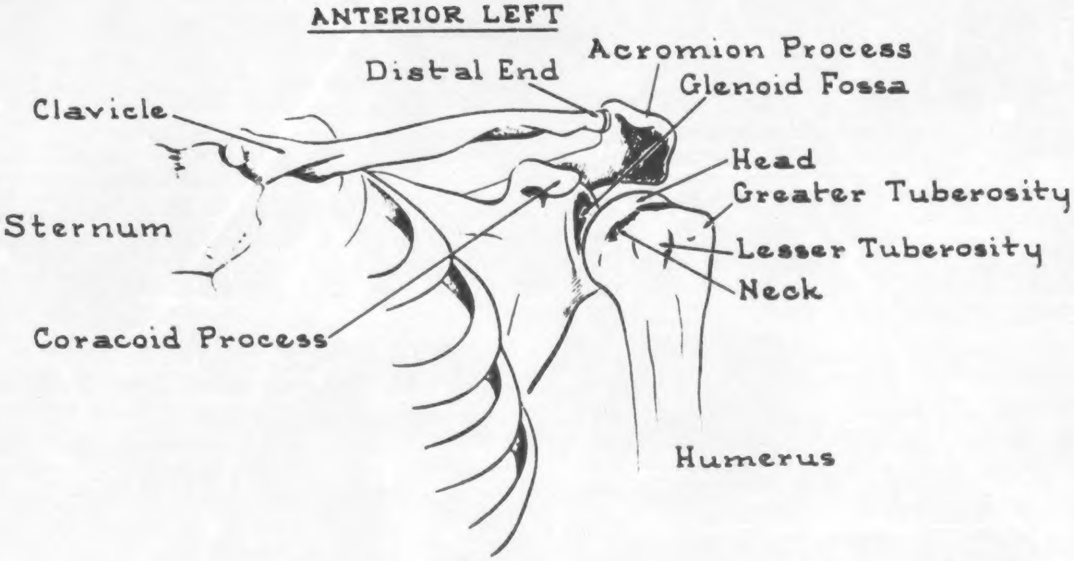


Figure 1-22. The shoulder.

8. Give the name of the large process that is located at the lateral portion of the scapular spine.

9. Name the oval depression at the lateral scapular angle.

10. What is the name of the projection that extends anterolaterally from the neck of the scapula?

11. What type of joint is the glenohumeral joint?

12. What two parts of the shoulder form the shoulder joint?

13. What two parts of the shoulder form the A.C. joint?

CHAPTER 2

Osteology of the Vertebral Column, the Ribs, and the Sternum

OUR STUDY of osteology continues with the vertebral column, the ribs, and the sternum. As with the extremities, we will present a somewhat complete review of the basic osteology. We will also discuss some material that will help you perform the quality control functions mentioned in the preface to this volume. We will begin our discussion with the vertebral column.

2-1. The Vertebral Column

Practically speaking, the spine is divided into five anatomic areas, each consisting of a specific number of vertebrae (see fig. 2-1). The most superior area is the cervical region, containing seven vertebrae. The thoracic spine is directly inferior to the cervical region and consists of 12 vertebrae. The third portion of the column is the lumbar region, composed of five vertebrae. Continuing down the spine, we see that the sacrum is one irregular vertebra, as is the coccyx at the lower end of the column. The sacrum and coccyx were discussed in Chapter 1.

214. Describe the anatomical parts of the lumbar spine.

The Lumbar Spine. Five typical vertebrae comprise the lumbar spine. They fit together to form the forward lumbar curve of the lower back. As you can see in figure 2-2, they are identified by number, from top to bottom. Characteristically, the lumbar are the largest of the typical vertebrae but have neither transverse foramina nor articular facets on their bodies. We will examine the parts that make up one of these vertebrae.

The body. This anatomic element forms the anterior part of a lumbar vertebra and is somewhat kidney shaped. In general, the body is rounded anteriorly and flattened posteriorly. The superior, inferior, and posterior surfaces are concave.

The pedicles. The pedicles extend posteriorly as short, bony projections on both sides of the posterior surface of the vertebral body. They connect the remaining vertebral parts with the body.

The laminae. These bony projections extend posteromedially from the pedicles to complete the vertebral arch by connecting the transverse processes to the spinous process. The vertebral arch is the largest part of the vertebral foramen, which consists of the pedicles, the articular, spinous, and transverse processes, and the laminae.

The articular processes. There are four articular processes—two superior and two inferior. The superior processes are located at the junction of the pedicles and the laminae. From here, they extend upward and face posteromedially. In turn, the inferior processes project downward from the junction and face anterolaterally to join with the superior articular process of the adjoining vertebra.

The spinous process. This is a single, bony projection attached to the vertebral arch. It extends posteriorly from the midpoint of the laminae junction.

The transverse processes. These processes arise from the pedicle-laminae junctions in L-1, L-2, and L-3, and from the pedicle-body junctions in L-4 and L-5. They are directed horizontally and slightly backward.

The intervertebral discs. The intervertebral discs are the shock absorbers for the vertebral column. Though they are integral parts of all sections of the spine, we will discuss them now and you can apply this knowledge to the discussions that follow. Each disc is composed of an outer layer of fibrocartilaginous material, called annulus fibrosus, and an inner area containing the pulpy substance, nucleus pulposus. The discs are extremely elastic and provide the cushioning effect needed to preclude or limit the transmission of shock from one end of the spine to the other.

The joints. Lumbar intervertebral joints are, for all practical purposes, of the same basic construction as those of the cervical and thoracic regions. Refer to figure 2-3 as you read.

The intervertebral joints are located between the bodies of typical vertebrae. The articular surfaces of each vertebral body join the intervertebral discs to form amphiarthrodial joints. Apophyseal or interarticular joints are formed by the inferior articular processes of one vertebra in articulation with the superior articular processes of the vertebra directly below it. The lumbosacral (sacrovertebral) joint is the point of union between the fifth lumbar vertebra and the sacrum.

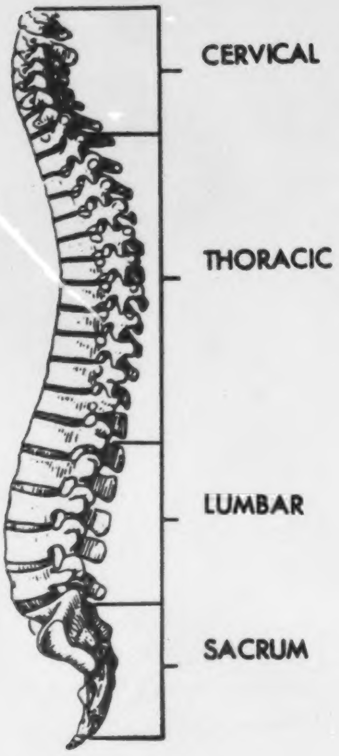


Figure 2-1. The spine.

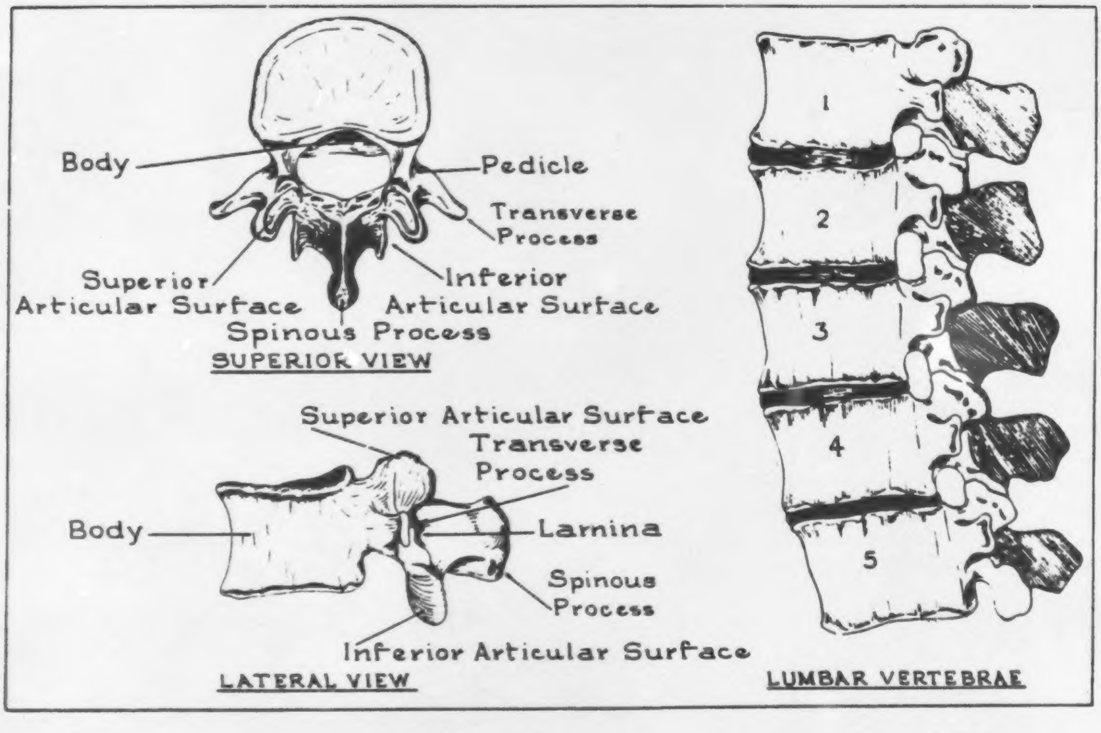


Figure 2-2. The lumbar spine.

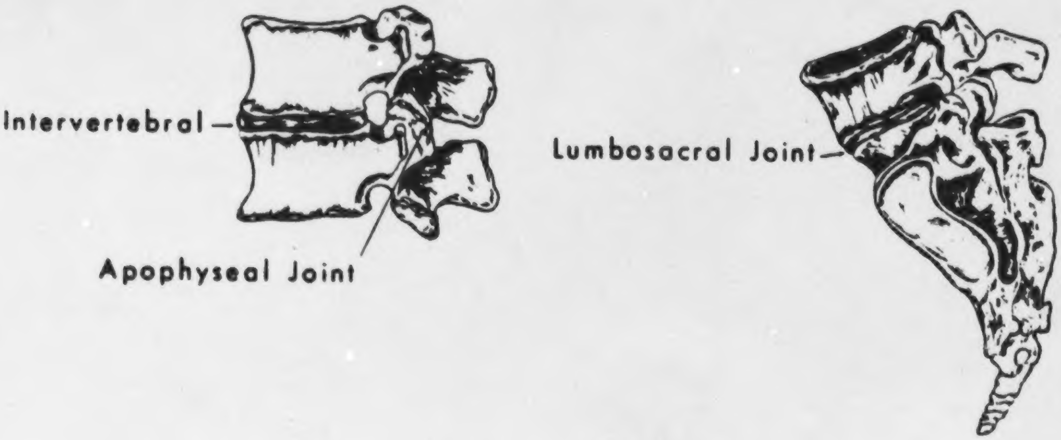


Figure 2 3. Joints of the lumbar spine.

Exercises (214):

1. How many vertebrae are in the lumbar spine?

2. Name the large anterior portion of a lumbar vertebra.

3. Where are the pedicles located?

4. What part of a lumbar vertebra is located between the spinous and transverse processes?

5. Specifically, what do the inferior articular processes of the fourth lumbar vertebra articulate with?

6. What is the name of the most posterior projection of a lumbar vertebra?

7. How many transverse processes has each lumbar vertebra?

8. What is the name of the outer layer of an intervertebral disk? The inner layer?

9. Where are the intervertebral joints of the lumbar spine?

10. Name the lumbar joints that are formed by the articular processes.

11. What two parts form the lumbosacral joint?

215. Given selected statements pertaining to the thoracic spine, indicate which are true and which are false. If you indicate "false," explain your answers.

The Thoracic Spine. The thoracic vertebrae are located at the posterior portion of the bony thorax and form the posterior (kyphotic) curve. They include 12 typical vertebrae, to which 12 pairs of ribs are attached. By reference to figure 2-4, you can see that they are identified by a number such as T-1, T-2, etc. They increase in size from T-1 to T-12. All of the thoracic vertebrae are typical in that they have the 12 characteristic parts. However, they are further distinguished by the costal articular facets located on the transverse processes of T-1 through T-10 and on the posterolateral surfaces of the bodies of all thoracic vertebrae.

The typical thoracic vertebra. Except for the articular facets, a typical thoracic vertebra is much like a lumbar vertebra. The lateral surface has two articular facets on each side of T-1 through T-8 and one articular facet on each side of T-9 through T-12. The posterior surface is concave and thicker than the anterior surface. The transverse processes extend posterolaterally and support the ribs. The

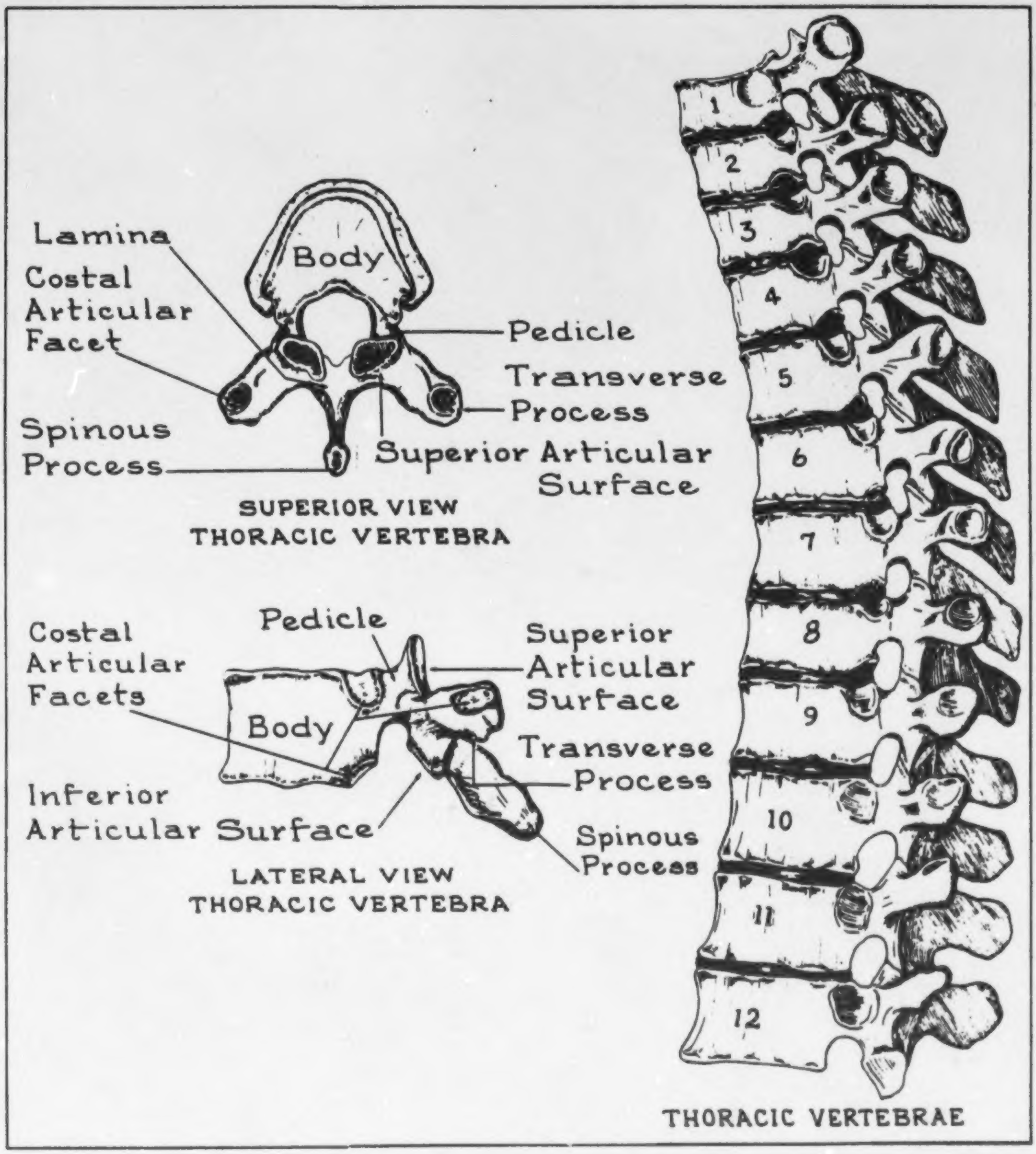


Figure 2-4. The thoracic spine.

spinous process is located posteriorly and extends backward and downward obliquely. The superior articular processes extend upward and posterolaterally. The inferior articular processes extend downward and anteromedially. The pedicles extend slightly upward and backward from each side of the posterior surface of the vertebral arch. The laminae extend posteromedially from the pedicle-transverse process junction to the spinous process. Figure 2-4 illustrates the structure of thoracic vertebrae and the lateral aspect of the thoracic spine.

Joints of thoracic vertebrae. The intervertebral and apophyseal joints are of the same type and formed by the same parts as the joints in the lumbar vertebrae. The costovertebral joints are between the vertebral bodies and the heads of the ribs. They are formed when the heads of the ribs articulate with the articular facets, or demifacets, of the vertebrae. The costotransverse joints, between the transverse processes of the vertebrae and the tuberclues of the ribs, are formed when the articular facets of the *transverse processes join the tubercles of the ribs.* This articulation is not present on the last two vertebrae (see fig. 2-5).

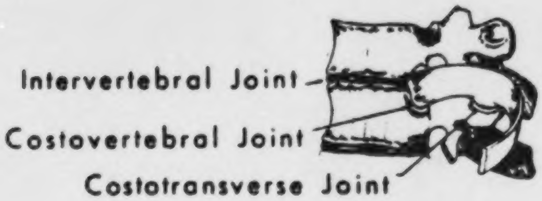


Figure 2 5. Joints of the thoracic spine.

Exercises (215):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. There are 12 thoracic vertebrae.

T F 2. Costal articular facets are located on the transverse processes of all thoracic vertebrae.

T F 3. All of the thoracic vertebrae bodies have at least one articular facet.

T F 4. A thoracic vertebra is considerably different from a lumbar vertebra.

T F 5. The heads of the ribs join the thoracic vertebra at the costovertebral joints.

T F 6. Costotransverse joints are present on the first 10 thoracic vertebrae.

T F 7. Thoracic vertebrae have no apophyseal joints.

216. Prove that you can describe the anatomical parts of the cervical spine by filling in the blank spaces in a series of sentences.

The Cervical Spine. Seven cervical vertebrae make up the cervical spine. Because of some peculiarities in the construction of certain of these vertebrae, we will briefly discuss their differences. Follow the discussion by noting the described characteristics in figure 2-6.

First cervical vertebra. The first vertebra may be described as being atypical, because it has no body or spinous process but has a larger vertebral foramen than does a typical vertebra. This vertebra is called the atlas, because it supports the head as the mythological Atlas supported the earth. It is round and has an anterior arch, a posterior arch, a posterior tubercle, two lateral masses, two superior articular facets, two inferior articular facets, and two transverse processes.

Second cervical vertebra. The second cervical vertebra is also atypical, because it has the odontoid process (a rounded, perpendicular piece of bone that arises from its body). The name for this vertebra is "axis," because it serves as the pivot point for the atlas.

Cervical vertebrae 3 through 7. The remainder of the vertebrae are similar to each other in construction. However, their bodies are smaller than the bodies of thoracic or lumbar vertebrae. Since each of them has 12 parts, each is considered a typical vertebra, though all have characteristics peculiar to cervical vertebrae. Each one (including the atlas and axis) has a foramen in each transverse process, through which veins, arteries, and nerves pass. Such transverse processes are found only in the cervical vertebrae. Another peculiar characteristic is the bifid (divided into two parts) spinous process. The seventh cervical vertebra is particularly distinctive in that its spinous process is long, bifurcated, and extends farther outward than the spinous process of the other cervical vertebrae.

Joints of cervical vertebrae. The joints of the cervical vertebrae are the atlanto-occipital joints (atlas and occipital bone), the atlanto-axis joint (atlas and axis), the intervertebral joints, and the interarticular joints. The atlanto-occipital joint is formed by the superior articular surfaces of the atlas in articulation with the condyles of the occipital bone of the skull. The atlanto-axial articulation is formed by the atlas and axis. The intervertebral and apophyseal joints are similar to those of other vertebrae (see fig. 2-7).

Exercises (216):

In the exercises that follow, fill in the blank spaces with one or two words as appropriate.

1. The ______ is the first cervical vertebra.

2. The ______ is the second cervical vertebra.

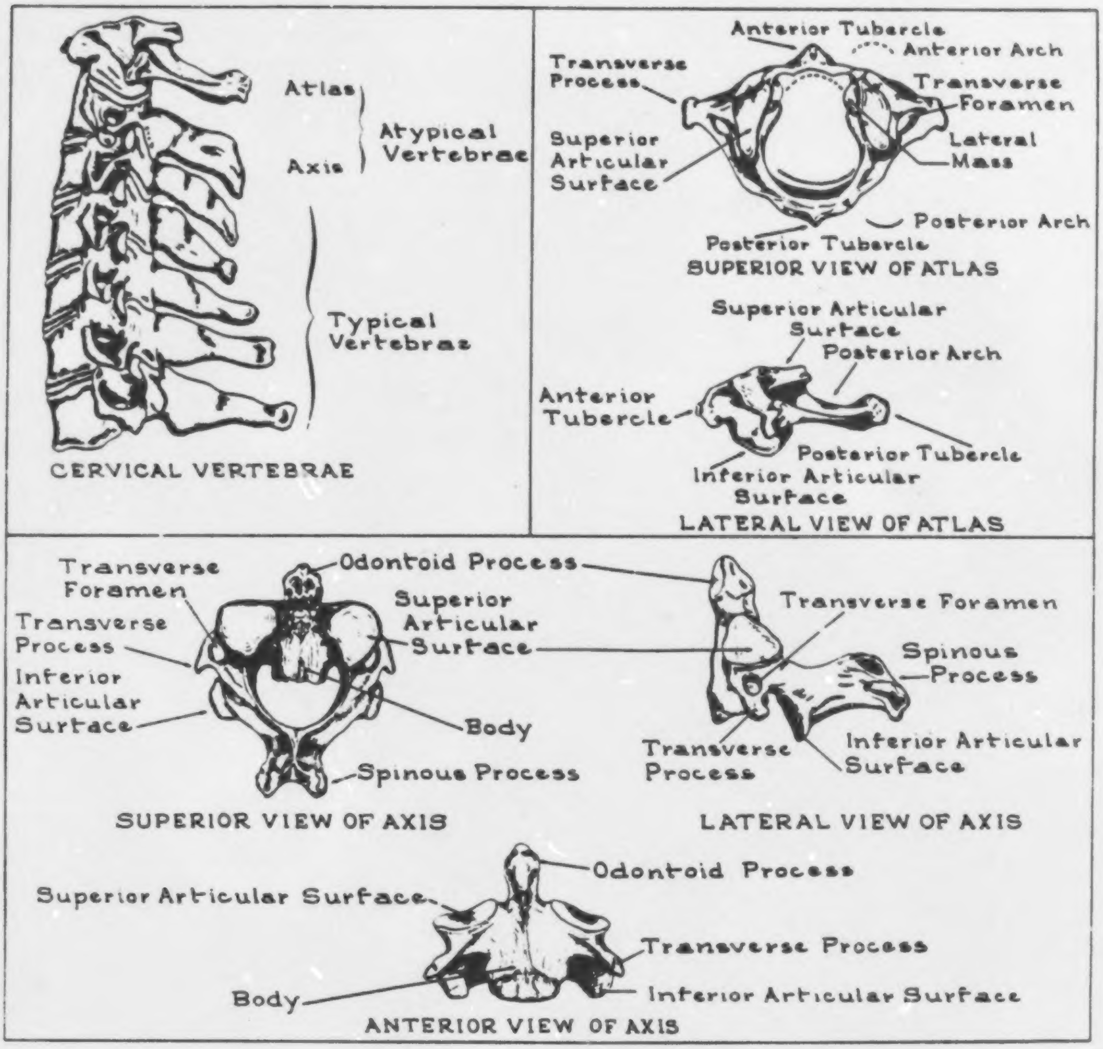


Figure 2-6. The cervical spine.

3. _____ cervical vertebrae have transverse foramina.

4. The _____ has no spinous process.

5. The odontoid process is part of the _____.

6. The _____ cervical vertebra has the longest spinous process.

7. Cervical spinous processes are _____.

8. The atlas articulates with the _____ bone to form the _____ joints.

9. The atlas articulates with the axis to form the _________ joint.

10. _____ cervical vertebrae are considered atypical.

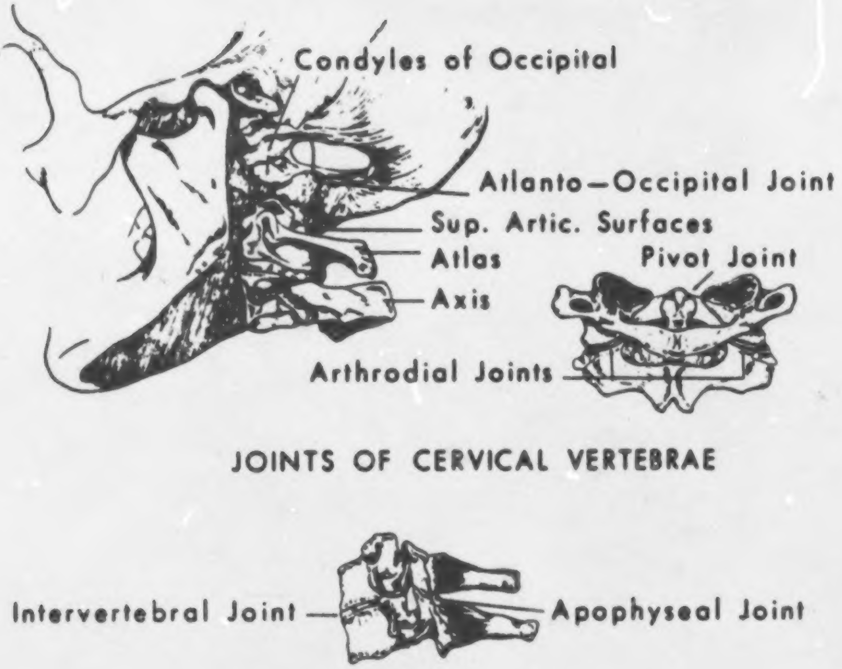


Figure 2-7. Joints of the cervical spine.

2-2. The Ribs and the Sternum

The area described as the ribs and the sternum includes the several parts of the sternum and the many types of joints involved.

217. List the three groups of ribs, give the number of ribs in each group, and explain each classification.

The Ribs. The ribs are curved, flat bones that form most of the posterior and anterior structure and all of the lateral structure of the bony thorax. Usually, there are 12 ribs on each side of the median plane of the thorax, extending from the 1st through the 12th thoracic vertebra. As you can see in figure 2-8, ribs are identified by number and by the side of the body in which they are located. The first seven pairs are considered true ribs. They are attached to cartilage, which joins directly to the sternum. The remaining five pairs are considered false ribs. The costal cartilage does not articulate directly with the sternum. Ribs 8, 9, and 10 articulate anteriorly with the costal cartilage of the ribs directly above them. Because they do not articulate anteriorly, ribs 11 and 12 are frequently called floating ribs.

Exercises (217):

In exercises 1 through 3 below, list the three groups of ribs, give the number of ribs in each group, and explain why they are classified as such.

1.

2.

3.

218. Describe the anatomical parts of the sternum.

The Sternum. The sternum, commonly called the breastbone, is long and flat and is located almost vertically at the midanterior part of the thoracic cage. The major parts and landmarks of the sternum are the manubrium, the body, the sternal angle, and the xiphoid process. The parts of the sternum are illustrated in figure 2-9.

Manubrium. The manubrium of the sternum is about 2 inches long and is the uppermost part of the sternum. It is thick and broad superiorly, and becomes narrower as it descends toward the body of the sternum. The superior surface contains the suprasternal notch, often called the manubrial notch. On both sides of this notch are the clavicular notches, where the clavicles articulate with the manubrium.

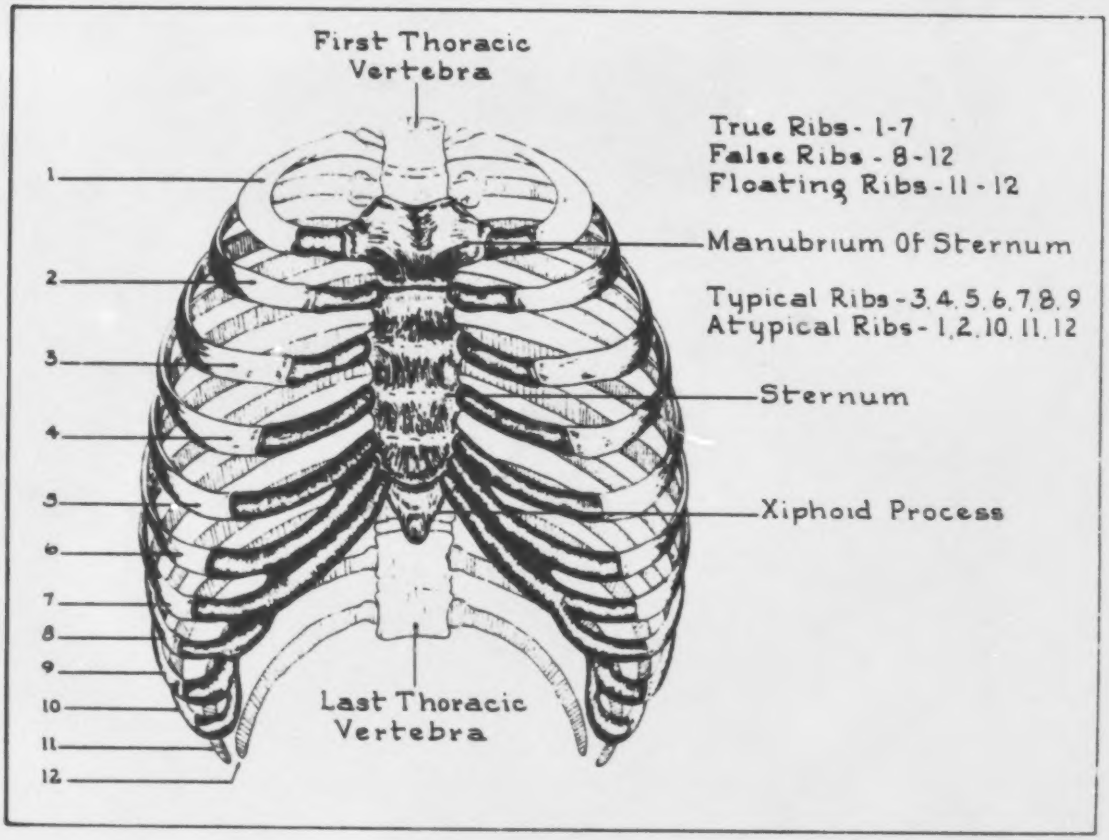


Figure 2 8. The ribs.

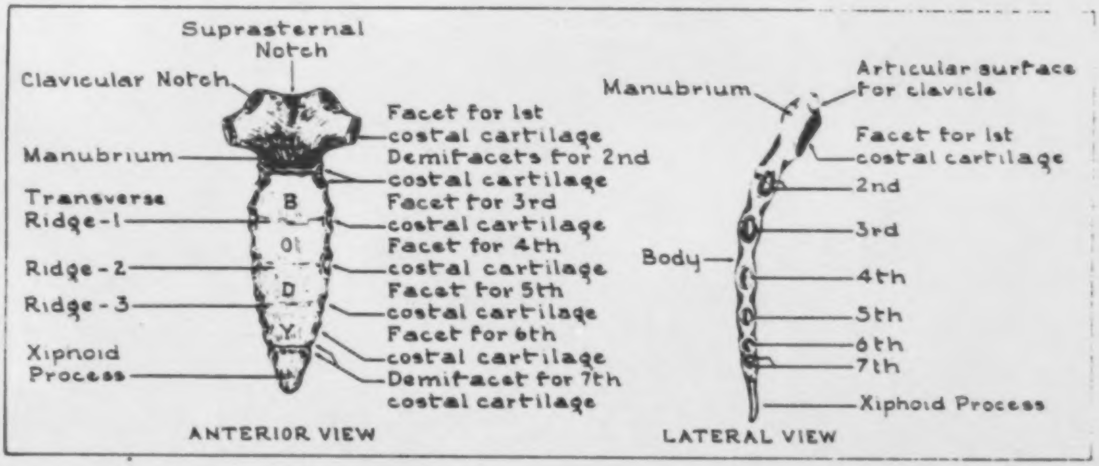

Suprasternal Notch
Clavicular Notch
Manubrium
Transverse Ridge-1
Ridge - 2
Ridge - 3
Xiphoid Process
B
O
D
Y
Facet for 1st costal cartilage
Demifacets for 2nd costal cartilage
Facet for 3rd costal cartilage
Facet for 4th costal cartilage
Facet for 5th costal cartilage
Facet for 6th costal cartilage
Demifacet for 7th costal cartilage
ANTERIOR VIEW
Manubrium
Articular surface for clavicle
Facet for 1st costal cartilage
2nd
3rd
Body
4th
5th
6th
7th
Xiphoid Process
LATERAL VIEW

Figure 2-9. The sternum.

The body, or gladiolus. The body of the sternum, also called the corpus, is about 4 inches long. The superior part of the body articulates with the inferior part of the manubrium. On each lateral border of the body are articular facets for ribs 2 through 7.

Sternal angle. The sternal angle, also called the angle of Louis, is formed by the articulation of the inferior border of the manubrium with the superior border of the sternal body.

Xiphoid process. The xiphoid, or ensiform, process forms the distal portion of the sternum. It is the smallest and thinnest of the three major sternal components and remains cartilaginous until advanced adulthood. Its posterior surface continues with the posterior surface of the sternal body, and each of its superolateral borders has a demifacet.

Exercises (218):

1. What is the name of the upper portion of the sternum?

2. What are the names of the three notches of the upper portion of the sternum?

3, Name the angle formed by the sternal body and manubrium.

4. In what part of the sternum is the xiphoid process?

219. Given a list of the joints of the ribs and the sternum, match each with an appropriate descriptive statement.

Joints of the Ribs and the Sternum. We have already discussed the costovertebral and costotransverse joints, so let's examine the other joints of the ribs and sternum. Refer to figure 2-10 to see these joints.

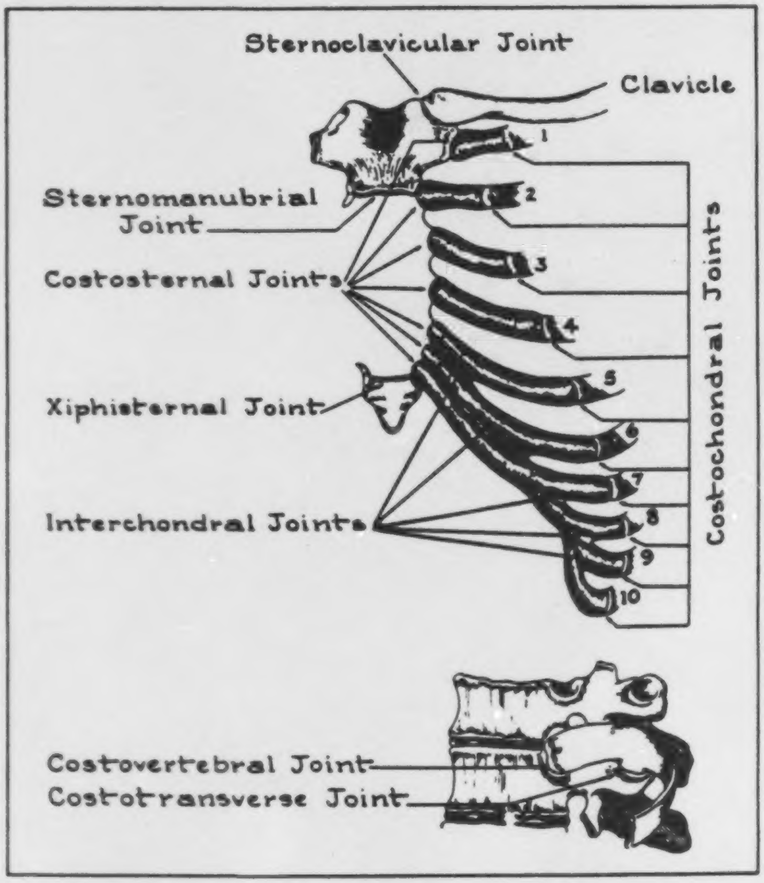


Figure 2-10. The costal joints.

Costosternal joints. Only the true ribs are involved in the costosternal joints, which are formed by the articulation of the costal cartilage of the ribs with the sternum. Only the first costosternal joint is synarthrodial; all of the others are diarthrodial joints.

Interchondral joints. The costal cartilage of ribs 6, 7, 8, 9, and 10 articulate with each other to form the interchondral joints.

Costochondral joints. These joints are formed by the costal cartilage in articulation with the sternal ends of the ribs.

Sternoclavicular joints. The sternoclavicular joints are formed by the sternal ends of the clavicles in articulation with the clavicular notches of the manubrium.

Sternomanubrial joint. The sternomanubrial joint is formed by the inferior surface of the manubrium in articulation with the superior surface of the sternal body to form an amphiarthrodial joint. Although the manubrium remains stationary, the sternal body is able to move anteriorly and posteriorly. This movement is important in the mechanics of respiration.

Xiphisternal joint. The xiphisternal joint is formed by the superior surface of the xiphoid process in articulation with the inferior surface of the sternal body.

Exercises (219):

Match the joints in column B with the appropriate statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or not at all.

Column A	*Column B*
___ 1. Anterior ends of ribs articulate with costal cartilage.	*a.* Costosternal joints.
___ 2. Sternal body and xiphoid process join.	*b.* Interchondral joints.
___ 3. Manubrium joins with sternal body.	*c.* Costotransverse joints.
___ 4. Costal cartilage of ribs in articulation with each other.	*d.* Costochondral joints.
___ 5. Costal cartilage of true ribs joins with sternum.	*e.* Sternomanubrial joint.
___ 6. Clavical articulates with manubrium.	*f.* Xiphisternal joint.
	g. Sternoclavicular joint.
	h. Costovertebral joint.

CHAPTER 3

Osteology of the Skull, the Facial Bones, and the Paranasal Sinuses

PERHAPS NO other bony body parts are as difficult to demonstrate radiographically as are certain parts of the skull. The main reason for the difficulty is the many overlying structures. Many examinations require precise angulations of the skull, film, and CR. Evaluating the quality of skull radiographs is also difficult because of overlying structures. It is difficult both to position the skull properly and to evaluate the quality of the radiographs without a good working knowledge of osteology.

Our study of osteology continues in this chapter with the cranium, facial bones, and paranasal sinuses.

3-1. The Cranium

In our discussion of the cranium, we will examine the cranial bones and the cranial sutures, junctions, and fontanelles.

220. Name, locate, and describe the eight bones of the cranium.

The cranium has eight bones—one frontal, two parietal, two temporal, one occipital, one sphenoid, and one ethmoid. Use foldout I in the back of this volume as a reference while you study.

Frontal Bone. The frontal bone is the forehead, the anterior roof of the cranium, the superior part of the orbits, a part of the nose, and the anterior floor of the cranial fossa. In itself, it has two major parts the squamosal and the orbital. The squamosal part of the frontal bone makes up the forehead. Its outstanding parts are the frontal eminences, the supraorbital foramina, the zygomatic processes, the nasal process, the frontal sinuses, (discussed later in this chapter), and the sagittal sulcus. The frontal eminences are large, rounded, bony elevations located on each side of the anterior midline above the supraorbital ridges. The supraorbital ridges are the prominent bony ridges that form the upper anterior boundaries of the orbits and also mark the junction of the squamosal and orbital portions of the frontal bone. They can be easily felt under the eyebrows. The supraorbital foramina are the small holes that provide passage for the supraorbital nerve and the blood vessels. The zygomatic processes are prominent bony processes on the lateral parts of the supraorbital ridges, connecting the frontal and zygomatic bones. The nasal process is the piece of bone projecting downward and forward and extending from the nasion. It supports the bridge of the nose. The sagittal sulcus, a vertical groove on the internal surface of the frontal bone, is formed by the fusion site of the original two parts of the frontal bone. The orbital portions of the frontal bone, which make up the superior parts of the orbits, are thin, triangular plates.

Parietal Bones. The two parietal bones make up most of the lateral walls and the roof of the cranium. In front, they unite with the frontal bone, and on top, they unite with each other. The anterior, superior, and posterior borders are serrated for articulation with the frontal, parietal, and occipital bones. Inferiorly, they articulate with the temporal and sphenoid bones.

Temporal Bones. The two temporal bones form part of the inferolateral walls of the cranium, bilaterally. The parts of these bones that deserve special consideration are the mastoid processes, the petrous ridges, the styloid processes, the tympanic portions, the mandibular fossae, and the zygomatic processes.

Mastoid processes. These large, bony prominences are located on the inferoposterior part of each temporal bone, directly behind each external auditory meatus (EAM). They contain air cells of different sizes and shapes called mastoid cells.

Petrous ridges. These are the pyramidal wedges of bone that form the part of the cranial base between the sphenoid and occiptal bones. They also house the inner ear.

Styloid processes. The styloid processes are long slender projections extending forward and downward from the inferior part of the temporal bones.

Tympanic portions. Lying anterior to the mastoid processes and directly above the styloid processes, their anteroinferior portions make up the superior part of the mandibular fossae.

Mandibular fossae. These depressions are located in the anteroinferior portion of the tympanic parts of the temporal bones. They are also part of the temporomandibular joints, since they provide articulation for the condyloid processes of the mandible.

Zygomatic processes. These processes are slender bony projections extending anteriorly from the inferior aspects of the temporosquamosal areas just above each external auditory meatus (EAM). Their anterior ends are serrated for articulation with the zygomatic processes of the zygomatic bones, forming the zygomatic arches.

Occipital Bone. The occipital bone, which makes up part of the roof and the posteroinferior portion of the cranium, has these outstanding parts: the foramen magnum, the external and internal occipital protuberances, and the occipital condyles.

Foramen magnum. This foramen is a large opening in the base of the occipital bone, through which the lower parts of the medulla oblongata and spinal cord pass to the spinal column.

External occipital protuberance. The external occipital protuberance (EOP) is a bony prominence located in the middle of the area where the occipital bone curves inward to form the posterior portion of the cranial base. This prominence may be easily felt.

Internal occipital protuberance. The internal occipital protuberance is located on the internal surface of the occipital bone in the same area as the external protuberance, and marks the junction of the four divisions of the occipital bone.

Occipital condyles. These condyles, lying on each side of the foramen magnum on the external surface, are oval-shaped, smooth, bony prominences, which articulate with the superior articular surfaces of the atlas. The skull joins the vertebral column at this point.

Sphenoid Bone. The sphenoid bone is located at the base of the cranium where it makes up the middle portion of the cranial floor. Its major parts are the body, the optic foramina, the sella turcica, the anterior and posterior clinoid processes, the great wings, and the lesser wings.

Body. The body of the sphenoid bone is the middle part, hollowed out to form two sphenoid sinuses, which lie directly behind the nose.

Optic foramina. These two foramina, one on each side, are located at the anterolateral part of the body of the sphenoid bone. Through these holes, the optic nerves and vessels leave the cranial vault and enter the orbits.

Sella turcica. This "Turkish saddle," located on the superior surface of the body of the sphenoid bone, is a saddle-shaped depression on which the pituitary gland is situated.

Clinoid processes. These bony projections arise from the lesser wings and dorsum sella respectively. They bend backward and forward over the sella turcica to form a partial protective roof over the pituitary gland.

Great wings. These wings extend laterally from the sides of the body. They form part of the floor of the cranium, a small part of its lateral walls just anterior to the temporal bones, and the posterior part of the lateral walls of the orbits.

Lesser wings. These wings lie anterior to the sella turcica, and are thin, triangular pieces of bone that extend laterally from the body. Part of the posterior roof of the orbits is formed by their inferior surface.

Ethmoid Bone. The ethmoid bone, the smallest of the cranial bones, is located behind the bridge of the nose and forms part of the anterior base of the cranium and the orbits. Its major parts are the cribriform plate, the crista galli, the perpendicular plate.

Cribriform plate. The plate has a vast number of foramina (cribriform foramina) through which the olfactory nerves (nerves of smell) pass to enter the nasal cavity. Articulating with the ethmoid notch of the frontal bone, this plate forms the roof of the nasal cavity.

Crista galli. This bony projection, shaped like a shark's fin, extends upward from the cribriform plate. It is the attachment for the anterior brain.

Perpendicular plate. This thin, bony projection extends downward from the inferior surface of the cribriform plate and forms part of the nasal septum.

Exercises (220):

1. What bones make up the cranial roof?

2. Which bone forms the superior portion of the orbits?

3. Name the foramen that is located on the anterior portion of the frontal bone, just above the orbits.

4. Which portion of the frontal bone makes up the forehead?

5. Describe the sagittal sulcus of the frontal bone.

6. What bone(s) join posteriorly with the occipital and anteriorly with the frontal?

7. The mastoid process is part of what bone?

8. Name the pyramidal wedges of bone that are part of the temporal bones.

9. What part of the temporal bone helps form the temporomandibular joint?

10. On which bone is the tympanic portion?

11. Name the large foramen in the occipital bone.

12. With what part(s) of the occipital bone does the first cervical vertebra articulate?

13. What palpable bony prominence is located on the occipital bone?

14. What bone makes up the mid-portion of the floor of the cranium?

15. Through what foramina do the optic nerves and vessels enter the orbits?

16. In what specific location is the pituitary gland?

17. What processes located on the sphenoid bone partially protect the pituitary gland?

18. The great and lesser wings are part of what bone?

19. Which is the smallest cranial bone?

20. What portion of the ethmoid bone forms the roof of the nasal cavity?

21. Give the specific location of the cristi galli.

22. What is the thin projection extending inferiorly from the bottom of the cribriform plate?

221. Given a list of the cranial sutures, match each with the bones that unite to form them.

The Cranial Sutures. The cranial sutures are as follows:

(1) Coronal suture—the frontal bone in articulation with the parietal bones.
(2) Sagittal suture—the two parietal bones in articulation with each other.
(3) Lambdoidal suture—the occipital bone in articulation with the parietal bones.
(4) Squamosal suture—the temporal bone in articulation with the parietal bone.
(5) Sphenosquamosal suture—the sphenoid bone in articulation with the temporal bone.
(6) Sphenofrontal suture—the sphenoid bone in articulation with the frontal bone.
(7) Sphenoparietal suture—the sphenoid bone in articulation with the parietal bone.
(8) Occipitomastoidal suture—the occipital bone in articulation with the mastoid process of the temporal bone.
(9) Parietomastoidal suture—the parietal bone in articulation with the mastoid process of the temporal bone.

Exercises (221):

Match the cranial suture in column B with the bones, in column A, that unite to form it. Place the letter of the column B item in the space provided in column A. Each column B item may be used once or not at all.

Column A	*Column B*
___ 1. Occipital-parietals.	a. Sphenoparietal.
___ 2. Parietals.	b. Parietomastoidal.
___ 3. Occipital-mastoid process.	c. Lambdoidal.
___ 4. Frontal-parietals.	d. Sagittal.
___ 5. Temporal-parietal.	e. Sphenosquamosal.
___ 6. Sphenoid-temporal.	f. Squamosal.
___ 7. Parietal-sphenoid.	g. Sphenofrontal.
	h. Coronal.
	i. Occipitomastoidal.

222. Given a list of the cranial junctions, match each with (1) the sutures that unite to form them, and (2) the corresponding cranial fontanelles.

Cranial Junctions. The cranial junctions are as follows:

(1) The bregma—the anterior junction of the coronal and sagittal sutures.

(2) The lambda—the posterior junction of the sagittal and lambdoidal sutures.

(3) The asterion—the posterolateral junction of the lambdoidal, squamosal, occipitomastoidal, and parietomastoidal sutures.

(4) The pterion—the anterolateral junction of the squamosal, sphenosquamosal, sphenofrontal, and sphenoparietal sutures.

Cranial Fontanelles. The cranial fontanelles are holes in the cranium at several junctions of the cranial bones. Usually, they are found only in infants and represent the future sites of the cranial junctions. The ossification of the fontanelles usually is complete at 2 years of age. There are six fontanelles—one anterior, one posterior, two anterolateral, and two posterolateral.

The anterior fontanelle. Often called the frontal fontanelle, the anterior fontanelle is located where the two parietal bones join the frontal bone. Usually, it is the future site of the bregma and is the last fontanelle to ossify.

The posterior fontanelle. Often called the occipital fontanelle, the posterior fontanelle is located where the two parietal bones join the occipital bone. It is the future site of the lambda.

The anterolateral fontanelles. Often called the sphenoidal fontanelles, the anterolateral fontanelles are located bilaterally at the junction of the parietal bones with the sphenoid and frontal bones. They are the future sites of the pterion.

The posterolateral fontanelles. Often called the mastoid fontanelles, the posterolateral fontanelles are located bilaterally at the junction of the parietal bone with the mastoid process of the temporal bone and the occipital bone. They are the future site of the asterion.

Exercises (222):

Match the cranial junctions in column B (1) with the sutures in column A that form them, and (2) with the corresponding cranial fontanelles in column A. Place the letter of the column B item in the space provided in column A. Each column B item may be used only once in each part.

Column A	*Column B*
Sutures	
___ 1. Squamosal, sphenosquamosal, sphenoparietal.	*a.* Asterion.
	b. Bregma.
___ 2. Occipitomastoidal, squamosal, lambdoidal, parietomastoidal.	*c.* Lambda.
	d. Pterion.
___ 3. Sagittal, lambdoidal.	
___ 4. Sagittal, coronal.	
Fontanelles	
___ 5. Posterolateral.	
___ 6. Anterolateral.	
___ 7. Anterior.	
___ 8. Posterior.	

3-2. The Facial Bones

The facial bones are the maxilla, lacrimal, zygomatic, palatine, nasal, inferior nasal conchae, vomer, and mandible.

223. Given a list of statements pertaining to the facial bones, state whether they are true or false. If you believe they are false, explain your answer.

The following bones make up the facial portion of the skull—two maxillae, two lacrimal bones, two zygomatic bones, two palatine bones, two nasal bones, two inferior nasal conchae, one vomer, and one mandible. The maxillae, the zygomatic bones, and the mandible form most of the facial contour. See foldout 1 at the back of this volume.

Maxillae. The maxillae form the upper jaw and hold the upper teeth in place. They meet and fuse at the anterior borders of the face and in the midline. Also, they form part of the medial floor of the orbits, the medial part of the infraorbital ridge, the lateral parts of the nasal fossa, and the anterior part of the roof of the mouth. Each maxilla consists of the body, the frontal process, the infraorbital foramen, the infraorbital margin, the zygomatic process, the palatine process, the anterior nasal spine, and the alveolar process.

The body comprises most of the bone and has a large cavity, the antrum of Highmore, which contains the maxillary sinus. The frontal process of the maxilla extends upward to form part of the lateral border of the nose and the medial portion of the infraorbital margin. The infraorbital margin is the anteroinferior margin of the orbit formed partly by the maxilla. The infraorbital foramen is a small hole just below the center of the infraorbital margin, through which the infraorbital nerves and vessels pass to the cheeks. The zygomatic process extends laterally from the body and articulates with the maxillary process of the zygoma. The palatine process is a horizontal plate of bone extending medially to meet the corresponding bone of the other side to form the anterior part of the roof of the mouth and the floor of the nose. The anterior nasal spine is a sharp projection of bone on the lower part of the midanterior surface of the maxilla. The alveolar process is the portion of the maxilla that contains the cavities of different sizes and shapes which hold the teeth of the upper jaw.

Lacrimal. These are the smallest and most delicate bones of the facial skeleton. They are located bilaterally to form a small portion of the anteromedial part of the orbital walls. They also house the "tear" ducts.

Zygomatic. The two zygomatic or malar bones, often called the cheek bones, are located at the superolateral aspect of the face bilaterally and form the prominent portion of the cheeks and part of the orbits. The parts of each bone that deserve consideration are the frontosphenoidal, orbital, maxillary, and temporal processes. The frontosphenoidal process is the part that articulates with the zygomatic process of the frontal bone. The orbital process is the part that extends medially from the infraorbital margin to form part of the floor and lateral walls of the orbits. The lateral part of the infraorbital margin is formed by the anterior portion of the orbital process of the zygoma. The maxillary process is the part that articulates with the zygomatic process of the maxilla. The temporal process is the long, narrow projection that articulates with the zygomatic process of the temporal bone to form the zygomatic arches.

Palatine. The palatine bones are small L-shaped bones located behind the nose. The perpendicular part of each bone forms part of the lateral wall of the nasal cavity. The horizontal part of each articulates with the corresponding horizontal part of the other palatine to form the posterior part of the roof of the mouth.

Nasal. Two nasal bones form the bridge of the nose and articulate above with the nasal notch of the frontal bone; they project anterioinferiorly from this junction. Laterally, they articulate with the frontal processes of the maxillae.

Inferior Nasal Conchae. The inferior nasal conchae, also called the inferior turbinate bones, are long, thin bones located along the lateral walls of the nasal cavity.

Vomer. The vomer, a flat, thin bone, forms the posterioinferior part of the nasal septum and is located behind and below the perpendicular plate of the ethmoid bone. The upper border of its anterior part articulates with the inferior surfaces of the perpendicular plate of the ethmoid bone. The lower part of the anterior border articulates with the cartilage of the nasal septum.

Mandible. In the mandible, which makes up the lower jaw and houses the lower teeth, these areas should be studied:

Body. The body, the curved part of the bone, is shaped like a horseshoe extending from one mandibular angle to the other.

Symphysis. The symphysis, or symphysis menti, is the anterior part of the body where the two L-shaped halves fuse together early in life--usually during the second year.

Mental foramen. The mental foramina are located about 1¼ inches on each side of the symphysis menti below the level of the second premolar (bicuspid) tooth on the anterior surface of the body of the mandible.

Angle. The angles of the mandible are the rounded areas of the lower jaws where the horizontal part of the body bends upward to an almost vertical position. They are located bilaterally at the posterioinferior part of the mandible and mark the junctions of the body and the rami.

Ramus. The rami of the mandible are those parts of the bone extending upward at about 45° from the angles of the mandible at the posterior aspects of the bone, bilaterally.

Mandibular foramen. The mandibular foramina are holes at the center of the medial surface of each ramus.

Coronoid process. The coronoid processes extend from the superoanterior border of the rami.

Condyloid process. The condyloid processes are bony projections extending from the superoposterior borders of the rami. Each process has two parts—the neck and the condyle.

Mandibular notch. the mandibular notches are the semicircular, or half-moon, depressions between the coronoid and condyloid processes of the rami.

Exercises (223):

Indicate whether the following statements are true or false. If you indicate false, explain your answer.

T F 1. There are 14 facial bones.

T F 2. The bones that form the upper jaw are the maxillae.

T F 3. The antrum of Highmore is in the zygoma.

T F 4. The infraorbital foramen is part of the maxilla.

T F 5. The two palatine processes of the maxillae help form the upper margin of the nasal cavity.

T F 6. The lacrimals are small bones that form a small portion of the orbital walls.

T F 7. The prominent portions of the cheeks are formed by the two maxillary bones.

T F 8. The frontosphenoidal process of the zygoma articulates with the zygomatic process of the frontal bone.

T F 9. The zygomatic arches are formed entirely by the zygomatic bones.

T F 10. The palatine bones form the posterior portion of the roof of the mouth.

T F 11. There are two nasal bones that form the bridge of the nose.

T F 12. The inferior nasal conchae are located along the medial walls of the orbits.

T F 13. The vomer forms part of the nasal septum.

T F 14. The area between the mandibular angles is the mandibular body.

T F 15. The symphysis of the mandible is laterally located with respect to the mental foramen.

T F 16. There is only one mental foramen.

T F 17. The mandibular angle is located between the corocoid and condyloid processes.

T F 18. The mandibular foramina are located on the rami.

T F 19. The condyloid process is anterior to the coronoid process.

T F 20. The intercondylar notch is located between the coronoid process and the condyloid process.

3-3. The Paranasal Sinuses

There are four paranasal sinus categories: the frontal sinuses, the maxillary sinuses, the ethmoidal sinuses, and the sphenoidal sinuses.

224. Match each of the four paranasal sinuses with a statement giving its location or other description.

The paranasal sinuses are cavities, normally filled with air, in the frontal, maxillary, ethmoid, and sphenoid bones. Their location, of course, is responsible for their names—frontal, maxillary, ethmoidal, and sphenoidal sinuses. For our discussion, we will begin by briefly describing each.

The Frontal Sinuses. These cavities are between the inner and outer tables of the frontal bone, in an area just above the bridge of the nose. These sinuses are highly irregular in shape and size, extending upward, backward, and laterally from a more or less central point just above and behind the bridge of the nose. They are separated by a thin, bony septum, which very often deviates from one side to the other. They are lined with mucous membrane, and each cavity communicates with the nasal cavity on its side by means of the frontonasal duct (see fig. 3-1).

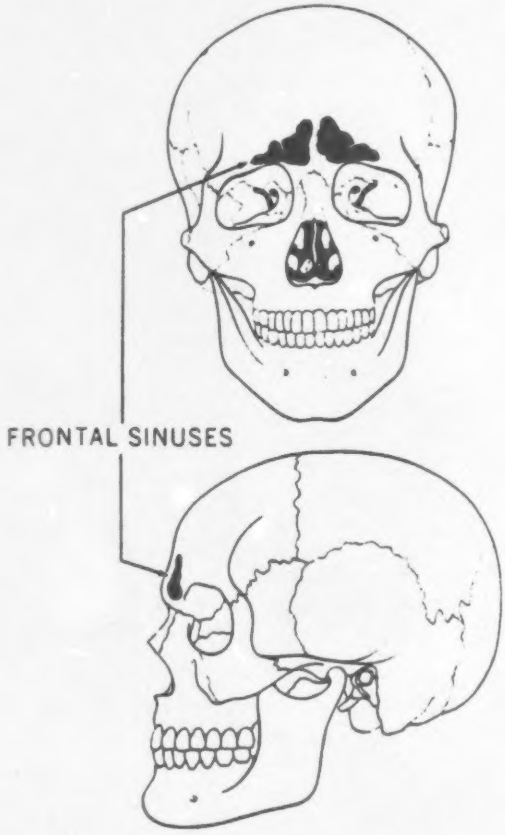


Figure 3-1. The frontal sinuses.

The Maxillary Sinuses. These are large, phyramidal cavities contained in the maxillae. They communicate to the nasal cavity through two small orifices in the superomedial aspects of each antrum. The floor of each cavity is formed by the alveolar processes of the maxillae, and if the sinuses are of average size, this floor is on a level with the floor of the nose. The maxillary sinuses, like the frontals, vary in size and configuration, even in the same patient. Both cavities are lined by a mucoperiosteal membrane, which is continuous with that of the nasal cavity. See figure 3-2.

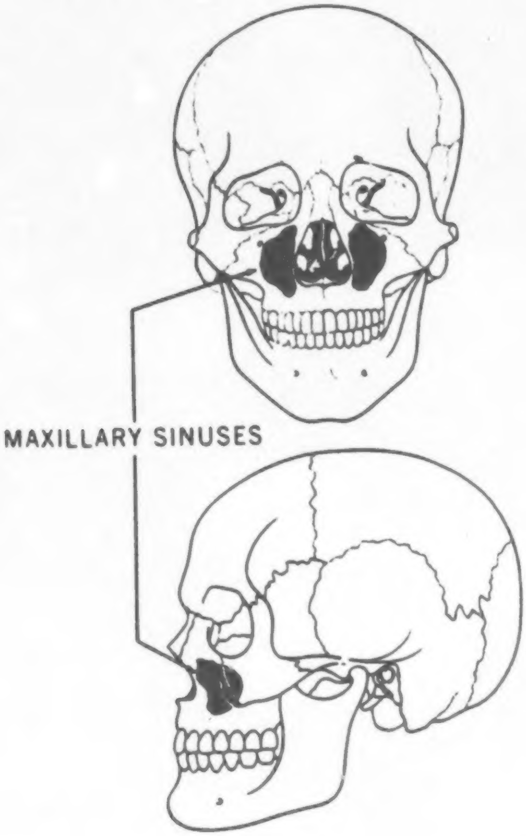


Figure 3-2. The maxillary sinuses.

The Ethmoidal Sinuses. These sinuses form the medial wall of each orbit as well as the superior portion of the nose on either side. The air cells of the ethmoids vary in number and size. There may be many small cavities or fewer large cavities. The anterior ethmoidal cells communicate with the middle nasal meatus. The posterior cells, located at the back of the nasal fossa, communicate with the superior meatus. The ethmoidal cells are lined by mucoperiosteal membrane continuous with that of the nasal cavity. See figure 3-3.

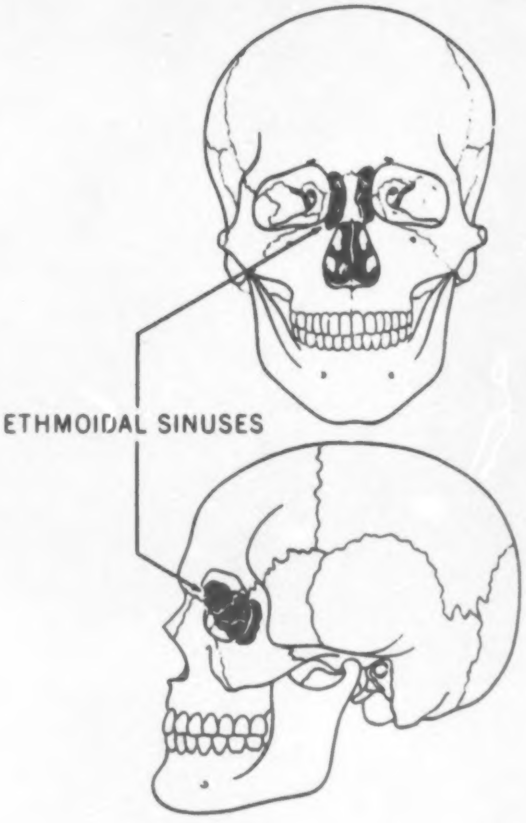


Figure 3-3. The ethmoidal sinuses.

The Sphenoidal Sinuses. The sphenoidal sinuses are directly posterior to the ethmoidal sinuses. They are a pair of cavities in the body of the sphenoid bone, separated from each other by a bony septum. This septum is rarely perpendicular to the base of the body, but is bent to one side or the other. This accounts for the asymmetrical appearance of the sinuses. In many cases they are continuous with the ethmoidal sinuses. The sphenoids are lined by a mucoperiosteal membrane that is continuous with that of the nasal cavity. They communicate with that cavity through the sphenoethmoidal recess, situated high in the posterior aspect of the nasal cavity (see fig. 3-4).

Exercises (224):

Match each column A statement about the paranasal sinuses with the correct sinuses in column B. Place the letter of the column B sinus in the space provided in column A. Each column B item may be used once or more than once.

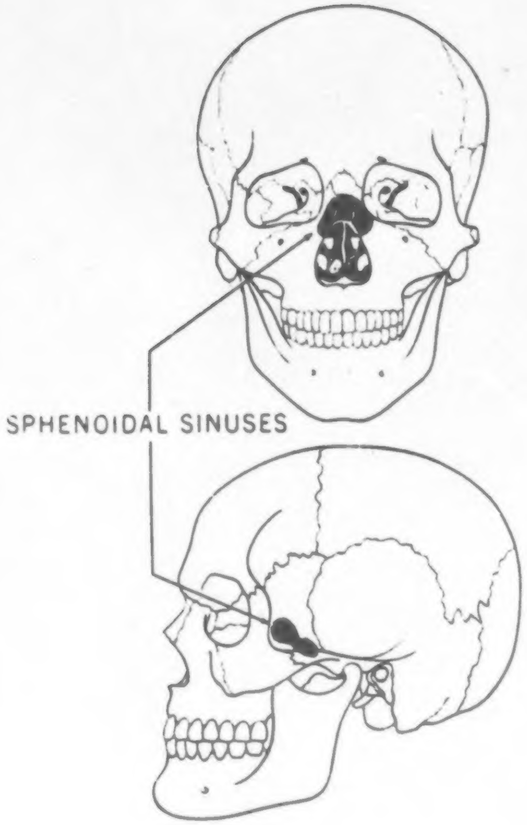


Figure 3-4. The sphenoidal sinuses.

Column A

____ 1. Located above and behind the bridge of the nose.
____ 2. Communicate with nasal cavity by means of the frontonasal duct.
____ 3. Located below the orbits.
____ 4. Located posterior to the ethmoidals.
____ 5. Form the medial walls of the orbits.
____ 6. Communicate with nasal cavity by means of the sphenoethmoidal recess.

Column B

a. Ethmoidal.
b. Maxillary.
c. Frontal.
d. Sphenoidal.

Positioning of the Extremities

OUR DISCUSSION of positioning begins with the extremities. As we mentioned in the preface to this volume, we will not discuss all of the standard positions. Neither will we discuss all the minor details associated with the positions that we include. We will, however, review some of the important points about selected standard projections, and the anatomy demonstrated by these selected projections, as well as some additional projections. We will also present certain information that will help you evaluate selected radiographs and perform the duties of a quality control technician.

4-1. The Lower Extremity

Our discussion of the lower extremity includes the toes, foot, calcaneus, ankle, knee and patella, and the hip. We will begin with the toes, foot, and calcaneus.

225. Given a written description of an AP projection of the foot, evaluate the projection and radiograph and determine whether they reflect proper procedures and/or meet prescribed standards.

The Toes, Foot, and Calcaneus. Some projections of the toes, foot, and calcaneus offer no special problems either in positioning or in evaluating the radiographs. Therefore, our discussion is limited to selected projections of these three parts.

Toes. When the plantar surface of the foot is in contact with the film, as for an AP projection of the toes, the phalanges are parallel with the film. Consequently, the interphalangeal joints are perpendicular. In order to properly demonstrate the interphalangeal joints, direct the CR perpendicularly through the joint spaces. If not, the angle of the CR causes the articular surfaces of each interphalangeal joint to appear superimposed over each other on the radiograph. The superimposition can obscure a minute abnormality in that area making correct interpretation difficult.

Foot. When the foot is in position for an AP projection, the metatarsals form a 15° angle with the film. If a vertical CR is used, the metatarsals will appear foreshortened on the radiograph. The other alternative is to direct the CR perpendicularly to the long axis of the metatarsals. Obviously, this slightly elongates those bones, but the elongation in this case provides a more diagnostic radiograph.

The talus and calcaneus are not adequately demonstrated on the AP projection of the foot due to superimposition of other structures. When the talus is to be demonstrated, include an AP radiograph of the ankle.

Exercises (225):

An AP projection of the foot (including the toes) is made with the CR angled 15° cephalic. Based on the information in the text, answer the items below.

1. Will the radiograph adequately demonstrate the third toe?

2. What specific areas of the third toe, if any, will not appear clear and diagnostic?

3. What correction(s) should be made, if any, in the projection to provide an AP radiograph that cleary demonstrates the proximal interphalangeal joint of the third toe?

4. Will the metatarsals appear distorted? If so, in what way?

5. Is the CR angle correct to demonstrate the metatarsals? If not, what should it be.

6. Which tarsal bones will be adequately demonstrated?

226. Describe the weight-bearing projections of the foot and the inferosuperior projection of the ankle, and name the anatomy demonstrated by the radiographs.

Weight-bearing projections of the foot are taken to show the relationships between the bones of the foot with the patient standing. The laterals are taken specifically for the longitudinal arch to demonstrate pes cavus (exaggerated height of the arch) and pes planus (lowering of the arch).

Your radiologist evaluates these radiographs under the assumption that the patient's weight is evenly distributed on the feet. Consequently, you should keep even weight distribution in mind when you make the radiographs. One way to help insure equal weight distribution is to stress its importance to the patient. In addition, you should have the patient remain in the same position for both comparison radiographs. This is no problem for the APs because you can take both feet simultaneously. For the laterals, if you have no commercial or "homemade" bench for this purpose, simply have the patient stand on two items of equal height (books will work nicely). Place two films vertically between the support items and feet with a sheet of protective lead between the films. Using a horizontal CR, expose one foot, swing the tube around and expose the other.

Calcaneus. Although the entire calcaneus cannot be demonstrated by the inferosuperior projection, most of it can be demonstrated if you use the correct foot position and CR angulation. The ankle should be flexed until the plantar surface of the foot is perpendicular to the film. A 40° CR angled toward the head projects the calcaneus away from overlying structures so that it can be demonstrated to the level of the trochlear process and sustentaculum tali. The talocaneal articulation also is visualized. If the proper position and CR angulation are not used, the calcaneus will appear foreshortened and more of the anterior portion will not be visualized because of the superimposition of other structures.

Exercises (226):

1. Why are lateral weight-bearing projections of the feet made?
2. Why is it important to have the patient maintain equal weight distribution on his feet during exposure for weight-bearing projections of the feet?
3. Give two ways to help insure equal weight distribution during radiography of weight-bearing projections of the feet.
4. What portion of the calcaneus is not demonstrated by the inferosuperior projection?
5. Specifically, how much of the calcaneus should be demonstrated by the inferosuperior projection?
6. What two specific positioning factors are important in taking an inferosuperior projection of the calcaneus?
7. If the procedures indicated in item 6 above are not followed, how is the radiograph likely to show the calcaneus?

227. Given written descriptions of certain projections and radiographs of the ankle, evaluate them for compliance with prescribed procedures and standards; recommend corrective measures if necessary.

The Ankle. While most of the bony structures of the ankle are well demonstrated on the AP and lateral projections, a portion of the lateral malleolus is not well demonstrated because of its superimposition over the talus. Since most ankle injuries involve the lateral malleolus, it is important to provide at least one radiograph that projects the malleolus clear of overlying structures. If properly performed, the 45° medial oblique does this.

Perhaps, the most common error made in positioning the ankle for the medial oblique projection is failing to flex the ankle joint as much as possible. If the joint is extended (the normal relaxed position of the ankle when the patient is sitting or lying on the table) the calcaneus is pulled up and under the lateral malleolus. The resulting superimposition on the radiograph obviously makes interpretation difficult.

Stress that AP projections of the ankle joint are made to diagnose a tear of the medial or lateral ligament by showing a widening of the joint space of the side in question. The complete stress series consists of the following projections: A standard AP, and AP with forced inversion, and an AP with forced eversion. The ankle must remain in the AP position for the stress studies, and the foot is forcibly turned medially for one projection and laterally for the other. The procedure for turning the foot depends upon your radiologist because the examination may be quite painful. One method is to have another person (other than radiology personnel) hold the foot in position during the exposure. Another method is to have the patient hold his foot in position with a traction strap around the ball of the foot. In either case, the ankle must be held in position by some external force.

Exercises (227):

1. Only AP and lateral radiographs are performed on an ankle with an injured distal fibula. Based upon the information presented in the text, is the examination comprehensive? Explain your answer and indicate corrective measures needed if any.

2. If a medial oblique projection of the ankle shows the lateral malleolus superimposed over the calcaneus, what is the probable cause and how should it be corrected?

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 3. Stress projections of the ankle are used to diagnose a ligamentous tear.

T F 4. The entire stress ankle examination consists of two AP projections—forced inversion and forced eversion.

T F 5. Applying stress to the ankle joint can be painful to the patient.

T F 6. For stress projections, an external force must be applied to hold the ankle in position.

228. Given a list of statements pertaining to selected projections and radiographs of the knee and patella, indicate which are true and which are false. If you indicate "false," you must explain your answer.

The Knee and Patella. To check an AP projection of the knee for the proper position, look at the general appearance of the structures and the joint space. If the knee is in the true AP position, the width of the spaces between the femoral condyles and the tibial condyles will be equal. Check the lateral for the proper amount of rotation by noting the femoral condyles—they should be superimposed over each other. Naturally, the medial condyle will be slightly larger than the lateral because of magnification. In addition, the space between the patella and the femoral condyles should be visualized. Also, on the lateral, the angle formed by the leg and femur should be approximately 135°.

The tunnel projection of the knee is made to demonstrate the intercondylar eminence (spine) of the tibia and the intercondyloid fossa. The projection can be made in a number of ways, but we will discuss only one method—Homblad's position. To perform this tunnel projection, have the patient kneel on the table so that the leg is parallel to the table surface. He should then lean forward until the femur forms a 70° angle with the table. Direct the CR perpendicularly to the intercondyloid fossa. Be sure to place the leg in the true PA position.

The axial projection of the patella (also called "sunrise" and "tangential") is made to demonstrate vertical fractures of the patella and the femoropatellar joint. A good axial projection shows the patella projected away from the femur with a clear demonstration of the joint space. In the case of an injury to the patella, a transverse fracture should be ruled out before an axial projection is performed. The fragments may be displaced by the acute flexion of the knee.

Exercises (228):

Indicate whether the following statements are ture or false. If you indicate "false," explain your answer.

T F 1. Superimposition of the femoral condyles is one indication of correct knee rotation for the lateral projection.

T F 2. The knee should be flexed 135° for the lateral projection.

T F 3. The width of the spaces between the femoral condyles should be checked for a properly positioned AP knee projection.

T F 4. The tunnel projection of the knee is taken to demonstrate vertical fractures of the patella.

T F 5. The Homblad projection of the knee is taken with the femur forming a 110° angle with the leg.

T F 6. For the Homblad projection of the knee, the CR and femur form a 20° angle.

T F 7. The axial projection of the patella is used to demonstrate vertical fractures.

T F 8. If the axial projection of the patella is properly positioned, the interspace between the femur and patella will be seen.

T F 9. Hyperflexion of the knee could aggravate the injury if a transverse fracture is present.

T F 10. Before performing an axial projection of the patella, you should rule out a vertical or transverse fracture.

229. Describe two methods for locating the head of the femur.

The Hip. While the AP projection of the hip joint is generally not difficult to perform, projecting the joint into a small cone field can be a problem if you cannot locate the joint. There are at least two ways to pinpoint the head of the femur. One method is to visualize a transverse plane through the most superior point of the greater trochanter and a sagittal plane 2 inches medial to the ASIS. They will intersect at the head of the femur, as shown in figure 4-1. You can also locate the head of the femur by drawing an imaginary line between the ASIS and the upper margin of the symphysis pubis. The head of the femur is 1 inch along another imaginary line that is perpendicular to, and bisects, the first line as shown in figure 4-2.

Exercise (229):

1. In your own words, describe how you would locate the head of the femur using each of the methods described in the text.

230. Describe the method for locating the center and the long axis of the femoral neck, and explain the procedure for performing a lateral hip projection.

When a fracture of the upper femur (neck) is suspected, it is often necessary to perform a lateral (Danelius-Miller) projection with the patient in the supine position. This is also true of an open reduction of the femoral neck because of the

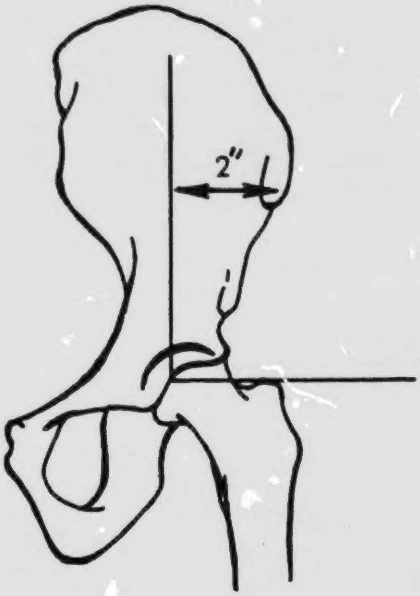


Figure 4-1. Location of the hip joint.

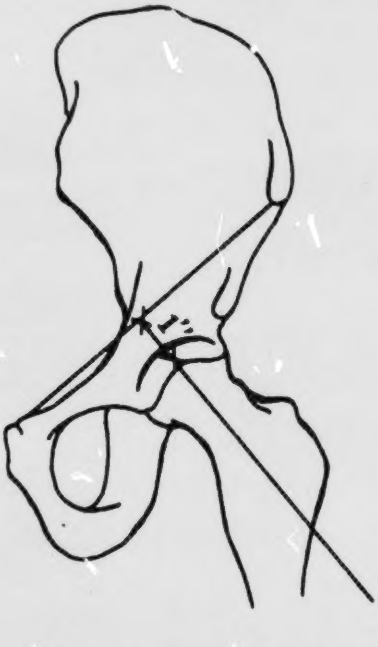


Figure 4-2. Location of the hip joint.

patient's position during the reduction. In such cases as this, it is important to locate the long axis of the femoral neck first. Otherwise, you will be "guessing" at the tube-part-film alignment and perhaps may even miss the part altogether.

Locating the long axis femoral neck is quite simple. Use the bony landmarks and imaginary lines shown in figure 4-2. The only difference is that the bisecting line is extended. It then parallels the long axis of the femoral neck (see fig. 4-3). When you have located the neck, you do the lateral hip projection by placing the film parallel with the neck and directing the CR perpendicularly to the film through the center of the femoral neck. See figure 4-4. Some other points to remember when you are performing this lateral projection of the hip are: (1) do not rotate or otherwise move the patient's leg—it could aggravate the injury, (2) use a small cone field to reduce film fog, and (3) be sure the film is in the vertical position.

Exercises (230):

1. In your own words describe how you would locate the center and long axis of the femoral neck.

2. Why is it important to locate the long axis of the femoral neck for a lateral projection?

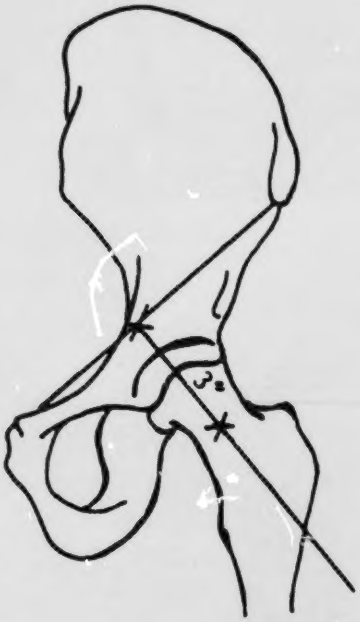


Figure 4-3. Location of the long axis of the femoral neck

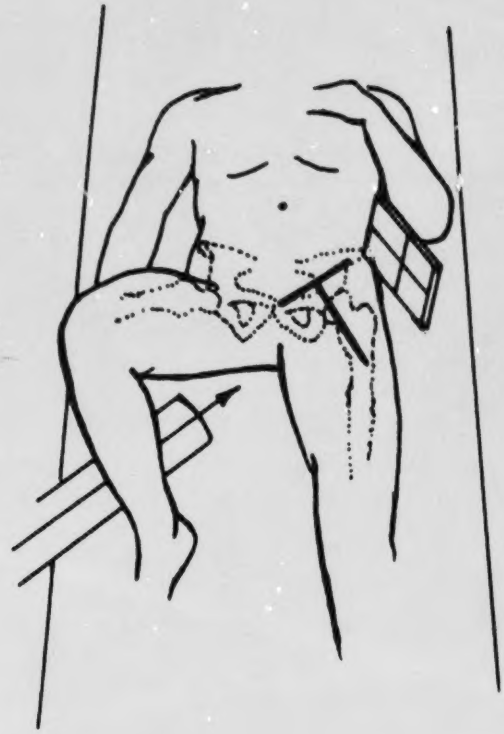


Figure 4-4. Relationships of tube-part and film for lateral hip.

3. At what specific point along the line that bisects the ASIS-to-symphysis-pubis line should you direct the CR for a lateral hip?

4. What precautionary measure should you take when performing a lateral hip?

5. Why should the X-ray field be restricted for a lateral hip?

4-2. The Upper Extremity

Our discussion of the upper extremity includes the fingers, carpal canal, elbow, and shoulder. We will begin with the fingers.

231. Given a written description of an oblique projection of the fingers, evaluate the projection and resultant radiograph and determine if they represent prescribed procedures and standards.

The Fingers. You, no doubt, have taken many radiographs of the fingers and probably have noticed the large number of small chip fractures near the interphalangeal joint spaces. While the PA and lateral projections are important in diagnosing these fractures, the oblique is equally important because it can reveal a fracture not seen on the other two radiographs.

The problem with the oblique is that it sometimes is not performed as it should be; consequently, a fracture may be missed. To demonstrate the interphalangeal joint spaces properly, the fingers must be positioned so that the joint spaces are perpendicular to the film. If not, there will be an overlapping of the articular surfaces of the phalanges and possibly of a "hidden" fracture. Notice the difference between the interphalangeal joints in figures 4-5 and 4-6. In figure 4-5, the fingers are parallel with the film; in figure 4-6, they are not.

The fingers can be positioned to properly demonstrate the areas referred to in a number of ways so long as they are supported to prevent part motion. One good device to use is a polyfoam step wedge, illustrated in figure 4-7. This step wedge can be made from any radiolucent material and can also be used for oblique projections of the hand and wrist.

Exercises (231):

An oblique radiograph of the ring finger is made with the finger forming a 35° angle with the table. Based on the information presented in the text, answer items 1 through 4 below.

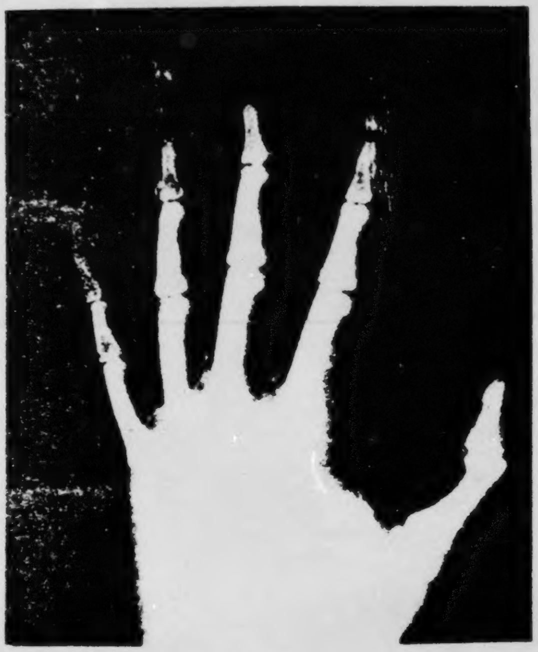


Figure 4-5. Oblique radiograph of the fingers showing good visualization of the interphalangeal joints.

1. What is the relationship between the interphalangeal joint spaces and the film?

2. Is the CR directed precisely through the joint spaces?

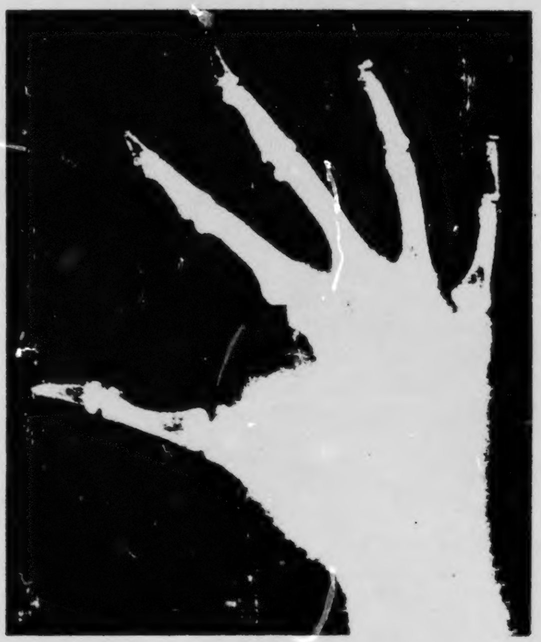


Figure 4-6. Oblique radiograph of the fingers showing superimposition of the articular surfaces of the interphalangeal joints.

Figure 4-7. The polyfoam step wedge.

3. How will the articular surfaces of each interphalangeal joint appear on the radiograph?

4. Is the finger properly positioned?

An oblique radiograph of the ring finger is made with the use of a polyfoam step wedge seen in figure 4-7. Based on the information in the text, answer items 4 through 8 below.

5. Is the finger parallel to the film?

6. What relationship exists between the joint spaces and the film?

7. How will the articular surfaces of the interphalangeal joints appear on the radiograph?

8. Of the two oblique projections mentioned in the exercises above, which one is preferred? Why?

232. Complete statements describing the procedure for performing a projection of the carpal canal, and name the bony structures demonstrated on the radiograph.

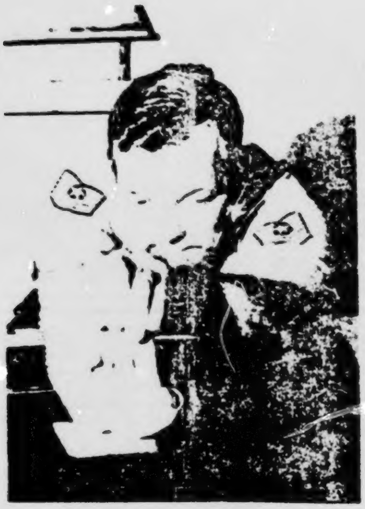


Figure 4-8A. Position of the hand for visualization of the carpal canal.

Figure 4-8B. Position of the hand for visualization of the carpal canal.

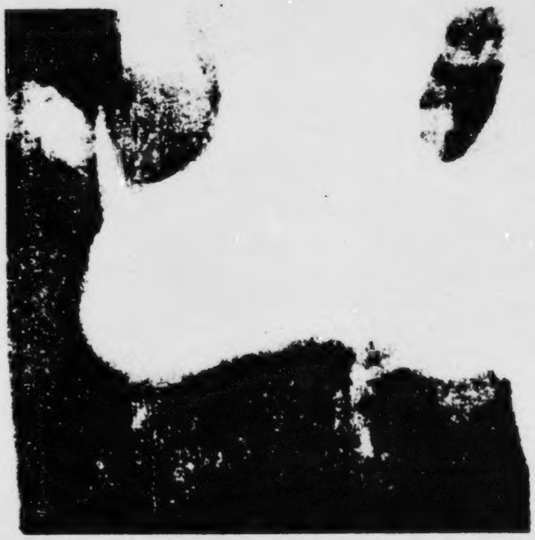


Figure 4-9. Radiograph of the carpal canal.

The Carpal Canal. The carpal canal is the anterior concavity of the wrist formed by the carpal bones. Because of the concave surface, it is difficult to visualize, by the standard projections, the volar aspect of some of the structures. The Gaynor-Hart projection can reveal or confirm fractures of the pisiform, triangular, capitate, hamulus process of the hamate, and the greater and lesser multangulars.

To perform the Gaynor-Hart projection, have the patient extend the wrist as much as possible so that the long axis is vertical or near vertical. To support the forearm, place a three-quarter inch radiolucent pad under the wrist. Rotate the hand slightly toward the radial side of the wrist to separate the hamulus process and pisiform. Direct the CR through the carpal canal at an angle of 30° (from vertical). See figures 4-8A, 4-8B, and 4-9.

Exercises (232):

Fill in the blanks below with the appropriate word, or answer the questions as indicated.

1. Demonstrating the ________ aspect of some carpal bones by standard projections is difficult because of the ________ of the surface.

2. Fractures of what parts can be visualized or confirmed by the Gaynor-Hart projection?

3. The long axis of the hand should be ________ or near vertical for the Gaynor-Hart projection.

4. A pad placed beneath the wrist to demonstrate the carpal canal supports the ________.

5. When performing the carpal canal projection, the ________ is ________ away from the ________ side of the wrist to provide an unobstructed view of the ________ and ________.

233. Given written descritions of selected projections and radiographs of the elbow, evaluate them and determine whether they represent prescribed procedures and standards; recommend corrective actions if necessary.

The Elbow. Our discussion of the elbow centers around some of the common errors made in performing the standard projections and in the resulting radiograph. We will also discuss some additional projections used to dmonstrate specific areas around the elbow.

AP projection. The AP projection of the elbow should be made with the hand supinated. any amount of pronation rotates the elbow medially and demonstrates an oblique projection—the amount depends upon the degree of pronation. A sandbag placed across the patient's hand prevents him from inadvertently pronating the hand.

Lateral projection. To obtain a true lateral projection of the elbow, there are a few things to keep in mind. In addition to the elbow, place the wrist and hand in the lateral position. If the hand is pronated you may not be able to detect the difference on the radiograph but the head of the radius is not in the lateral position. This could result in a missed fracture of the radial head.

When the elbow is in position for the lateral, the forearm is normally angled slightly downward, which causes the distal numerus to rotate. The radiograph will show the medial epicondyle extending posteriorly from the distal humerus. You can correct this rotation of the humerus easily by elevating the forearm slightly (about 1 inch).

For a specific demonstration of the radial head, four laterals can be made with the hand in the various positions shown in figure 4-10.

Oblique projection. The medial oblique projection of the elbow demonstrates a near lateral view of the coronoid process clear of overlying structures. The elbow should be rotated 40° to 45°. Too little rotation of the elbow does not turn the coronoid near enough to lateral. Consequently, it is seen "on end" or almost as it appears on the AP. Too much rotation of the elbow partially obscures the coronoid process because the radial head is superimposed.

The lateral oblique is a good projection for demonstrating the radial head. Part rotation is 45°. Be sure to keep the elbow joint extended for the exposure.

Jones' projection. Jones' projection of the elbow is taken to demonstrate the olecranon process. It is also used instead of the AP projection when the elbow is hyperflexed because of injury or treatment. Figure 4-11 shows the Jones' projection. Notice that the hand and wrist have been rotated so that the thumb is on the lateral side of the patient's shoulder.

Exercises (233):

An AP radiograph of the elbow shows slight medial obliquity. Based on the information in the text, answer items 1 and 2 below.

1. What is the probable cause of the obliquity?

2. What should you recommend to the specialist to correct the position?

3. A lateral radiograph of the elbow shows the medial epicondyle on the posterior side of the humerus. Is this a true lateral? If not, how should it be corrected?

A patient is positioned for a lateral elbow with the volar surface of the hand flat on the table. Based on the information in the text, answer items 4 through 6 below.

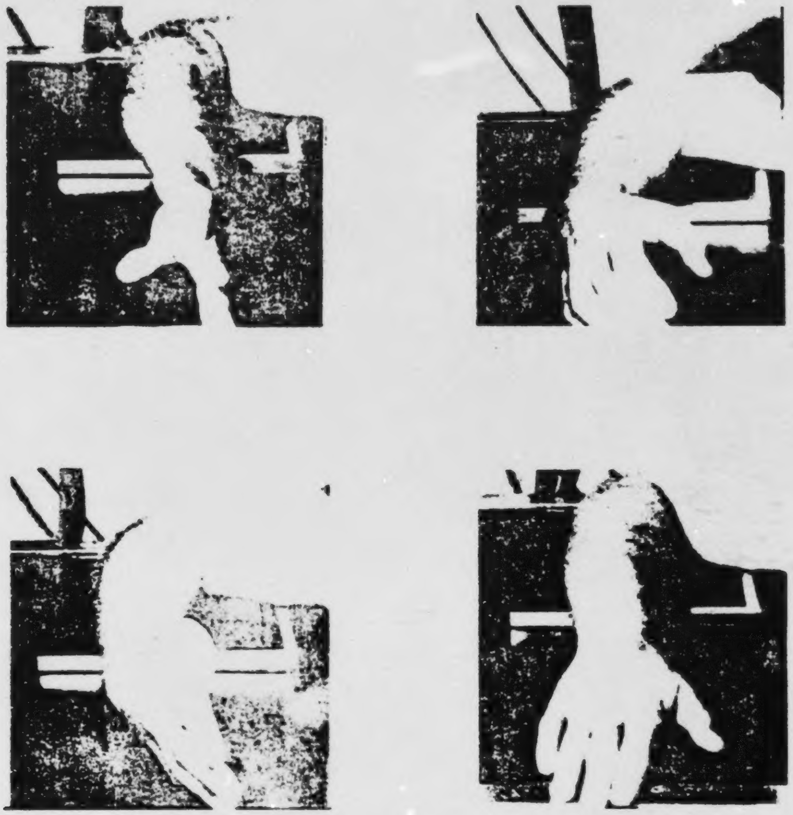


Figure 4-10. Position of the hand and arm for multiple radial head laterals.

4. Is the position correct?

5. What could be missed on the radiograph and why?

6. How should the position be corrected?

7. To demonstrate a fracture of the radial head, __________ lateral projections can be made with the __________ in different positions.

Two medial oblique radiographs of the elbow are made. Radiograph A shows the coracoid process projected almost in the AP position. Radiograph B shows the coracoid process superimposed over the radial head. Based on the information presented in the text, answer items 8 and 9 below.

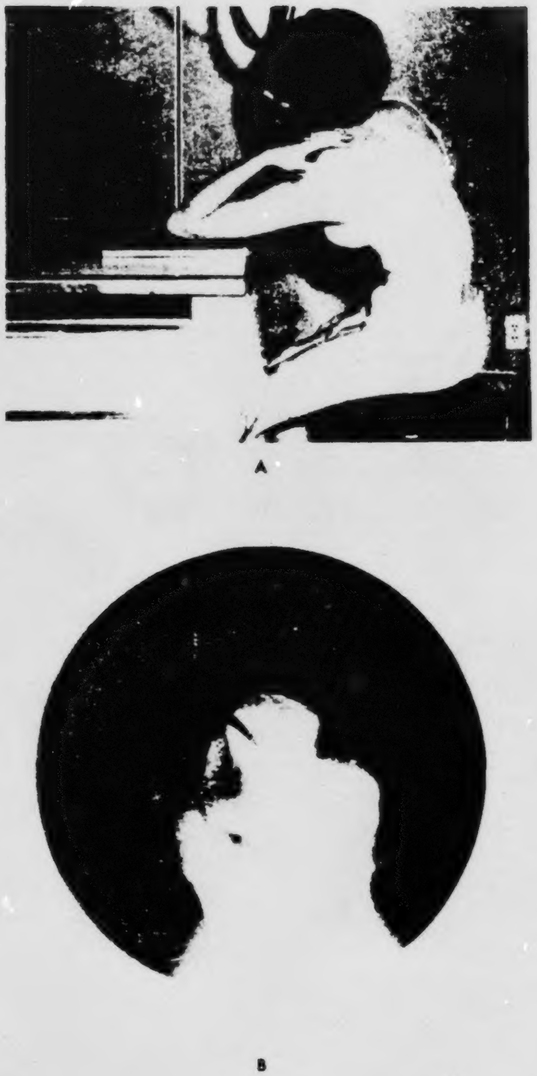
8. What is wrong with the position on radiograph A? How should it be corrected?

9. What is wrong with the position on radiograph B? How should it be corrected?

10. A 45° lateral oblique projection can be used to demonstrate the ____________________.

234. Given three radiographs of a dry humerus, classify them as neutral, external, or internal rotation.

Rotation Projections of the Shoulder. Classifying the rotation radiographs of the shoulder is simply a matter of recognizing the position of the proximal humerus. We will discuss three such positions designated as internal, external, and neutral rotation. As you study these positions, keep in mind



A. Position
B. Projection

Figure 4-11. Jones' projection of the elbow.

that the degree of arm rotation in your department depends upon your radiologist and may or may not be the same as described here. However, you should have little trouble adapting the information we present here to any rotation projection of the shoulder.

Neutral rotation. When a line through the humeral epicondyles is parallel to the table top, the humerus is in the neutral or AP position. In this position, the lesser tuberosity is shown superimposed over the humerus a little toward the medial side. The head of the humerus is seen in the oblique position since it extends posteromedially from the humerus. The greater tuberosity is shown on the lateral side, although not so prominently as in the external rotation position.

External rotation. In this position, a line through the epicondyles forms a 45° angle with the table top. The greater tuberosity and humeral head are seen in profile and consequently well visualized. You can also see the depression of the anatomical neck between the greater tuberosity and head. The lesser tuberosity is superimposed over the lateral portion of the humerus.

Internal rotation. when the arm is internally rotated so that a line through the epicondyles forms a 45° angle with the table top, the arm is in internal rotation. When this is the case, only the superior portion of the head is well visualized, since the rotation moves most of the head behind the other structures. The lesser tuberosity is shown in profile on the medial side of the humerus. The greater tuberosity is superimposed over other structures in the approximate center of the humerus.

Exercises (234):

Figure 4-12 shows three radiographs of a dry humerus. Study them and classify them as netural, external, or internal rotation. Write your answers below.

1. Radiograph A ______________________.

2. Radiograph B ______________________.

3. Radiograph C ______________________.

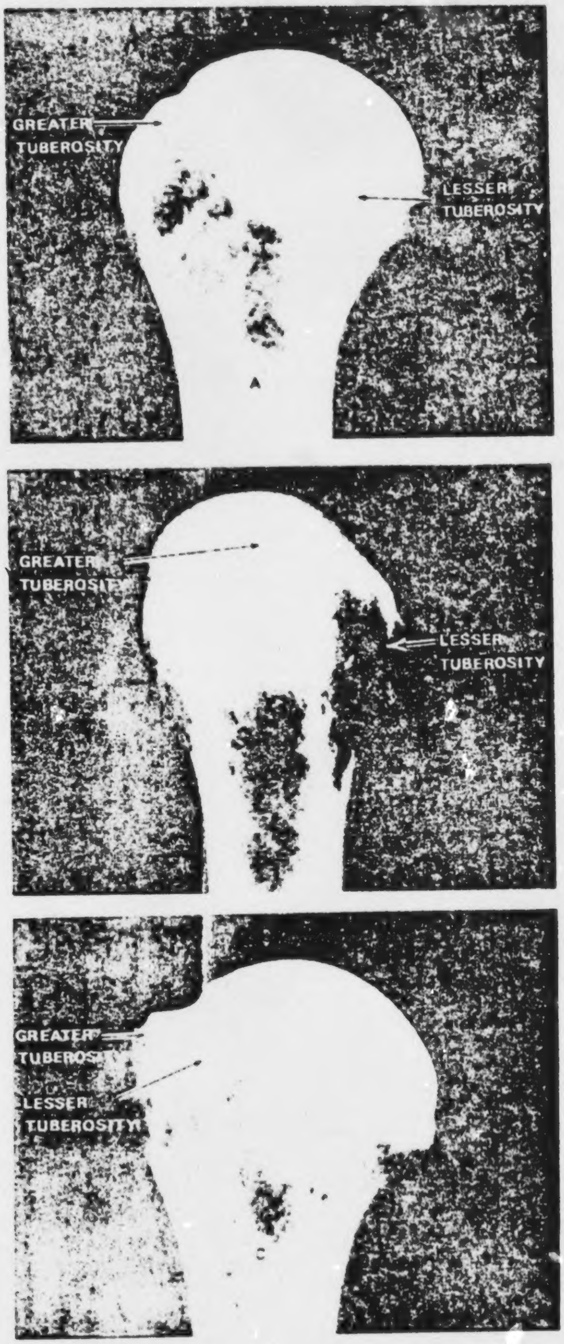


Figure 4-1[illegible]. Objective 234, exercises 1-3.

CHAPTER 5

Positioning of the Vertebral Column, Ribs, and Chest

WE WILL CONTINUE the subject of positioning with a discussion of the vertebral column, ribs, and chest. As we did in Chapter 4, we will omit most of the relatively simple projections, which cause no special problems, and include information concerning selected radiographs to help you determine the position, or rather the "improper" position, used. We will begin with the cervical spine.

5-1. The Cervical Spine

Our concerns in this section are the "open mouth" and oblique projections of the cervical spine—projections that often are not performed as they should be. In addition, we will describe the procedures to use in X-raying the cervical spine of a litter patient.

235. Given written descriptions of four AP radiographs of the atlas and axis, evaluate the radiographs and determine whether they meet prescribed procedures and standards; indicate corrective measures if necessary.

Atlas and Axis (Open Mouth). This projection is taken to demonstrate the atlas and axis in the AP position. For this projection, usually called an "open mouth odontoid" the patient's head must be precisely positioned; otherwise, the atlas and axis are not projected clear of overlying structures. To position the patient, have him open his mouth as wide as possible and adjust his head so that a line through the inferior edge of the upper incisors and the inferior border of the mastoid tip is perpendicular to the film. Use a vertical CR. Since the position is uncomfortable for the patient, be sure to have everything else ready so that you can make the exposure quickly. Also, have the patient say "Ah" during the exposure to prevent any movement of the jaw and to fix the tongue in the floor of the mouth. The shadow of the tongue is then projected below the vertebrae under study and does not interfere with the detail. As usual, for examinations in this area, have the patient remove any dentures he might have.

Usually, when the patient is improperly positioned for this projection, it is because his head is either flexed too little or too much. The result is the superimposition of the base of the skull or incisors (depending upon the direction in which the imaginary line is tilted) over the structures under study. You can easily check the position on the radiograph by noting the lower margins of the upper incisors and the base of the skull. If the base of the skull is lower than the incisors, the head is extended too much. If the two parts are reversed, the head is not extended enough. At times, although the head is tilted correctly and the incisors and base are in the same vertical line, there is still superimposition over the bertebrae. When such is the case, nothing can be done to improve this projection.

Exercises (235):

Four AP "open mouth" radiographs of the atlas and axis are made:

Radiograph A shows the lower margins of the upper incisors superimposed over the area under study. The base of the skull is projected above the upper incisors.

Radiograph B shows the base of the skull superimposed over the vertebrae. The lower margins of the upper incisors are projected above the base of the skull.

Radiograph C shows the base of the skull and the lower margins of the upper incisors superimposed over each other. Both of these structures are projected above the atlas. A dense shadow, representing the tongue, is superimposed over the axis.

Radiograph D shows the base of the skull and lower margins of the upper incisors superimposed over each other. Both of these structures are superimposed over the atlas and odontoid process.

Based upon the information presented in the text, answer the following questions about each radiograph.

Is the radiograph properly positioned? If not, what is specifically wrong with the position and how should it be corrected?

1. Radiograph A.

2. Radiograph B.

3. Radiograph C.

4. Radiograph D.

236. State the purpose of the oblique projections of the cervical spine, and answer key questions about them.

Oblique Projections of the Cervical Spine. The usual reason for making oblique projections of the cervical spine is to show the intervertebral foramina, although the pedicles are also seen, as well as the other cervical structures. The formaina open from the vertebrae at a 45° angle off both anterolateral aspects of the vertebrae. They also open slightly downward, 15° to 20°, from the vertebrae.

Obliques of the cervical spine can be taken erect or recumbent as well as with or without a grid. Also anterior or posterior obliques can be taken. These decisions rest with your radiologist. Keep in mind that the intervertebral foramina open from the anterolateral aspects of the vertebrae; therefore, posterior obliques demonstrate the formaina farthest from the film and anterior obliques show the foramina nearest the film.

To position the patient for an oblique projection, rotate the entire body 45° to coincide with the opened foramina. Turn the median plane of the head slightly more than 45° from its position perpendicular to the film to prevent the superimposition of the ramus of the mandible over the spine. Direct the CR to the fourth cervical vertebra so that it coincides with the inferiorly angled opening of the foramina. The CR is angled either in a caudad or cephalic direction, depending on whether the oblique is anterior or posterior.

Exercises (236):

1. For what specific reason are obliques of the cervical spine usually made?

2. Which oblique projection(s) demonstrates the structures indicated in item #1 above, on the right side of the vertebrae? On the left side of the vertebrae?

3. What is the specific part rotation and CR angulation for a right posterior oblique of the cervical spine? For a right anterior oblique?

4. If an oblique radiograph of the cervical spine show the ramus of the mandible superimposed over the vertebrae, what should you do to eliminate this superimposition on a subsequent radiograph?

237. With specific information about a patient brought to the radiology department on a litter, answer key questions about the types of projections and positions that will demonstrate his cervical vertebrae.

Cervical Spine Projections on a Litter Patient. When we speak of a "litter" patient in this case, we mean a patient who has injured his cervical spine and is on a stretcher or litter, usually in the supine position. This type of patient must be handled very carefully to prevent further injury and complications, such as a severed spinal cord.

When a patient is to be radiographed in this condition, the first thing you should do is to make a cross-table lateral of the cervical spine without moving the patient to the X-ray table, or changing his position on the litter. Show the radiograph to the radiologist or attending physician before doing anything else. This is very important because the physician may, after seeing the initial film, not want to move the patient at all until he is placed in traction.

Now, suppose the initial cross-table lateral does not show any abnormality. Your next course of action is determined by the physician. He may direct you to make AP and oblique projections with the patient still on the litter or to move the patient to the table for the remaining radiographs.

If the physician wants you to perform the remaining radiographs with the patient on the litter, he may want you to perform only an AP and let him look at the radiograph before going on with the obliques. If he wants obliques, you can easily perform them with the patient supine. All you have to do is place a cassette under the patient's spine and direct the CR 15° to 20° cephalically and 45° medially. In other words, the CR is directed through the intervertebral foramina as for conventional obliques, except that the tube is angled 45° instead of the patient. Ask the physician to supervise the lifting of the patient for the film placement. If it is not possible for the patient to move himself, be sure that the physician understands what you must do to place the film under the patient's neck. He can then tell you exactly how he wants you to lift the patient.

If the physician wants you to move the patient to the X-ray table for the remaining radiographs, again ask his supervision or guidance in moving the patient. You can perform the obliques on the table as on the litter, but you will have to remove the grid to prevent grid cutoff due to the 45° angle of the tube.

Exercises (237):

1. A patient is brought to the radiology department on a litter in the supine position. The physician suspects a fracture of C4. Describ the initial projection you should perform and why.

2. The cross-table lateral on the patient in item #1 above shows a fracture of C4. What is your next course of action, if any?

3. How much part rotation, if any, and what CR angulation and direction, if any, should you use for oblique projections on the patient in item #1 above?

4. What should you do to prevent grid cutoff if you are performing the obliques on the X-ray table on the patient in item #1 above?

5. Before moving or lifting the patient in item #1 above or adjusting his position, what action should you take?

5-2. The Lumbar Spine

AP and PA projections of the lumbar spine usually cause technicians few problems. Therefore, we will limit our discussion to the oblique and lateral projections.

238. Evaluate certain characteristics of specific oblique projections and radiographs of the lumbar spine.

Oblique Projections of the Lumbar Spine. The oblique projections of the lumbar spine are usually taken to demonstrate the apophyseal joints and the pars interarticularis. You will remember that the apophyseal joints are formed by the superior articular process of one vertebra and the inferior articular process of the next lower vertebra. These joints open from the posterolateral portions of both sides of the vertebrae at about a 45° angle. Usually, the joints can be visualized if the patient is rotated 45° in either the anterior or posterior oblique positions. However, the exact degree of angulation may vary from patient to patient, and after having seen the initial 45° radiographs, you may have to rotate the patient to some other angle to make the joint spaces visible. In fact, the degree of patient rotation is the most common positioning error made in performing these obliques, even when the joints are situated at a 45° angle. You can determine whether the patient has been rotated 45° from the AP or from the PA position by looking at the medial portion of the transverse process, seen on end as a dense circular area with a lucent center. If the joint spaces are not visualized and the medial portion of the transverse process is toward the anterior portion of the vertebral body, the patient is not rotated enough from the supine position. If the medial portion of the transverse process is toward the posterior portion of the vertebral body, the patient is rotated too much. This bony landmark should be in the approximate center of the vertebral body. In addition, the width of that structure changes with different amounts of body rotation. See figure 5-1. The pars interarticularis is the bony segment between the superior and inferior articular processes. If you can see the apophyseal joints on the radiograph, good visualization of the pars interarticularis is more or less automatic.

As we previously mentioned, posterior or anterior obliques of the lumbar spine can be made, depending upon your radiologist's preference. If posterior obliques are made, the joints and "pars" nearest the film are visualized. With anterior obliques, those farthest from the film are seen.

Exercises (238):

Three oblique radiographs of the lumbar spine are made. Radiograph A shows the medial portions of the transverse processes projected in the horizontal center of the vertebral bodies. Radiograph B shows the same structures projected toward the posterior portions of the bodies. Radiograph C shows them projected toward the anterior portions of the bodies. The relative (horizontal) widths of the processes are: Radiograph A—medium; radiograph B—narrow; radiograph C—wide. Based upon the information presented in the text, answer exercises 1 through 5 below.

1. Which radiograph shows approximately 45° rotation?

2. Which radiograph shows more than 45° rotation?

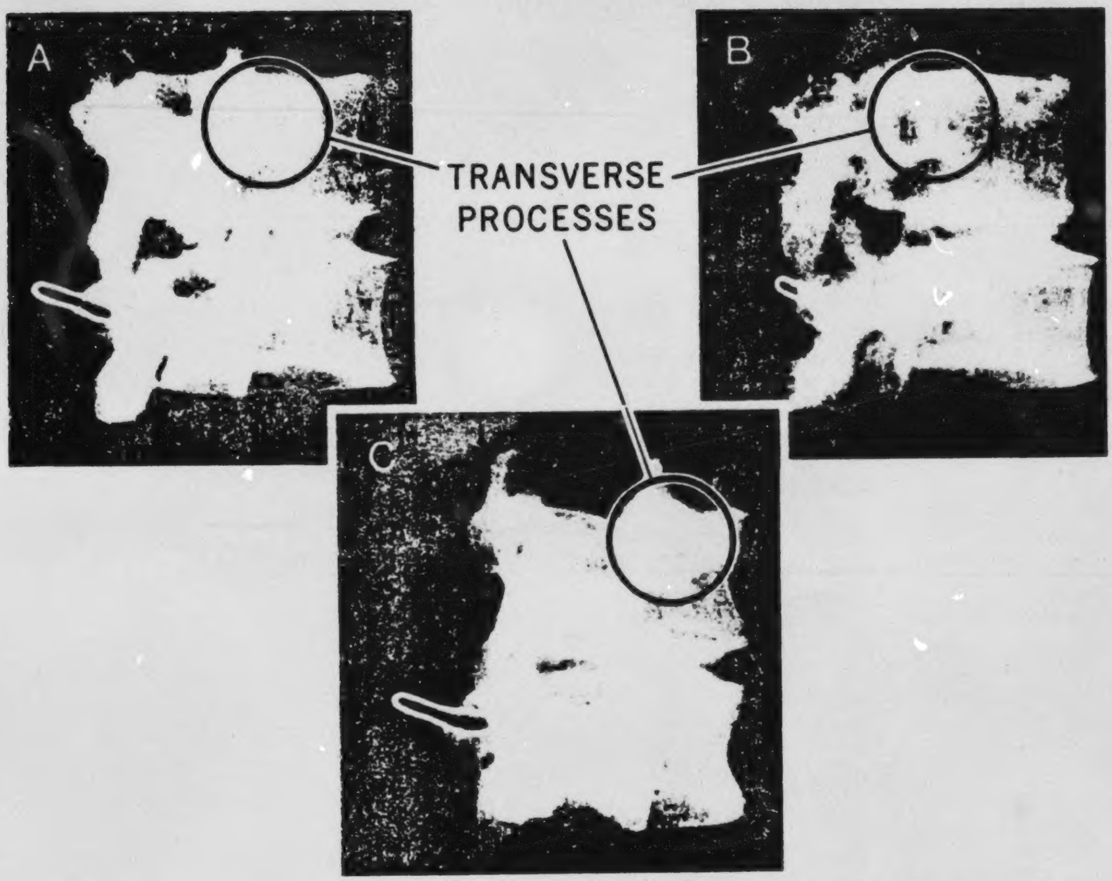


Figure 5-1. Three left posterior oblique radiographs of dried lumbar vertebrae showing how body rotation affects visualization of the apophyseal joints. A is correctly rotated. B is rotated too much. C is not rotated enough.

3. Which radiograph shows less than 45° rotation?

4. Which radiograph is most likely to demonstrate the pars interarticularis?

5. If radiograph A does not demonstrate the apophyseal joints, what can you assume about the joints?

6. A right posterior oblique of the lumbar spine is correctly made. Which (right or left) apophyseal joints are demonstrated?

7. A left anterior oblique of the lumbar spine is correctly made. What pars interarticularis (right or left) are demonstrated?

239. Given a list of statements pertaining to the lateral projection of the lumbar spine, indicate which are true and which are false. If you indicate "false," explain your answer.

Lateral Projection of the Lumbar Spine. A good lateral projection of the lumbar spine must show the interspaces between the vertebral bodies clearly without the superimposition of the superior and inferior articular surfaces. the interspaces are sometimes difficult to demonstrate because the lumbar spine has a tendency to "sag" (become curved) when the patient is in the lateral recumbent position. As a result, the long axis of the spine is not parallel with the film, and the interspaces are not perpendicular to the film. Consequently, on the lateral radiograph there may be an overlapping of the articular surfaces of the vertebral bodies over the interspaces.

The degree of the curvature of the spine depends upon the physical characteristics of the patient. The curvature of a patient with a relatively small waist and wide hips is greater than with a patient whose waist and hips are more nearly the same size. The long axis of the spine in a female usually sags more than that of a male because of the greater difference between her waist and hips. In certain patients, the size of the waist and hips is the same, and the long axis of the spine is actually parallel to the film when the patient is in the lateral recumbent position.

Usually, the best results are obtained if you use a vertical CR for the lateral lumbar projection. This means that you may have to place enough radiolucent material under the lumbar spine above the iliac crest and under the lower thoracic vertebrae to bring the long axis of the spine parallel with the table. Of course, some patients require more material than others because the degree of the spinal curvature varies. You can tell if the spine is parallel with the table by checking this alignment on the patient's back.

Instead of placing the spine parallel with the table, some technicians prefer to angle the CR caudally to compensate for the curvature of the spine. The degree of angulation depends upon the degree of curvature. A patient whose spine is nearly parallel with the table requires the least CR angulation. Usually, the average angle for male patients is 5° and for female patients 8°, for the reasons mentioned above.

Although, the problems stemming from the horizontal alignment of the vertebrae are perhaps the most difficult to overcome with the lateral lumbar projections, there are two other common errors made in the positioning. The first is failing to superimpose the knees and legs. This can cause anterior or posterior rotation of the vertebrae. Whether the rotation is anterior or posterior depends upon, and is consistent with, the relative position of the dependent leg. The second error is failing to elevate the dependent knee to hip level, which can cause anterior rotation of the vertebrae.

Exercises (239):

Listed below are several statements pertaining to the lateral projection of the lumbar spine. Indicate which are true and which are false. If you indicate "false," explain your answer.

T F 1. Normally, better radiographs result if the lateral is taken with the long axis of the spine parallel with the film.

T F 2. The intervertebral spaces must be perpendicular to the film.

T F 3. An angled CR is used in conjunction with a parallel spine-film relationship.

T F 4. In the lateral recumbent position, lumbar "sag" is usually greater in male patients.

T F 5. If you use a vertical CR, you always have to build up the spine.

T F 6. The amount of material used to bring the spine parallel with the film depends upon the patient's physical characteristics.

T F 7. The appearance of the intervertebral spaces on the radiograph is an indication of the correctness of the position.

T F 8. Superimposing the knees and legs can reduce the possibility of anterior, posterior rotation.

T F 9. To help prevent posterior rotation, you should elevate the dependent knee to hip level.

5-3. The Thoracic Spine, Ribs, and Chest

In this section, we will discuss the oblique projections of the thoracic spine, the ribs—with special emphasis on their relationships with the diaphragm—and the PA chest—strictly a discussion on quality control. We will begin with the obliques of the thoracic spine.

240. Correlate the position of the patient with the structures to be shown on the radiograph in oblique projections of the thoracic spine.

Oblique Projections of the Thoracic Spine. The oblique projections of the thoracic spine are usually taken to demonstrate the apophyseal joints. These joint spaces appear opened if they are seen at an angle of 20° from the vertical with the patient in the lateral recumbent position. If the patient is in this position, and the side remote from the film is rotated 20° forward, the joints nearest the film are demonstrated. If his elevated side is rotated backward 20°, the joints farthest from the film are visualized. For example, if the patient is in the right lateral recumbent position and his left side is rotated forward, the joints of the right side of the spine are visualized. If his left side is rotated backward, the left apophyseal joints are seen.

Whether you use anterior or posterior obliques depends upon your radiologist. There is a little difference in the part-film distance between the different types of obliques, so you shouldn't mix them. Comparing the sides is more difficult if the obliques are mixed. Also, be sure to elevate the lumbar and lower thoracic areas to place the thoracic spine parallel with the film.

Exercises (240):

1. If the patient is supine on the table, how many degrees should his left side be rotated away from the table to demonstrate the apophyseal joints on the left side? On the right side?

2. If a left posterior oblique is performed of the thoracic spine (median plane forms a 70° angle with the table), which apophyseal joints (right or left) are demonstrated?

3. If a left posterior oblique is performed of the thoracic spine, what other oblique should be performed?

241. Answer key questions about the technique and purpose of rib projections, and select from a list of respiratory phases the ones you would use in specific situations.

The Ribs. Some minor fractures of the ribs are, at times, difficult to demonstrate radiographically. One reason for this is that the overlying lung markings sometimes obscure the fracture site. Another reason is that some ribs lie above and some below the diaphragm. For the latter reason, it is difficult to select the proper technique for the ribs near the diaphragm unless you are sure of their location with respect to the diaphragm. As you know, ribs below the diaphragm require considerably more exposure than those above.

Diffusion of lung markings. The shadows of the lung markings can be diffused in extreme cases by using the shallow breathing technique during the exposure. The shallow breathing technique requires a longer exposure. Usually it covers two or three respiratory phases. Be sure to stress to the patient the importance of breathing smoothly and otherwise remaining perfectly still. Don't use the shallow breathing technique on a patient whose respiration is labored.

Rib-diaphragm relationship. You can also overcome the problem with the diaphragm by adjusting the patient's position and respiratory phase to place the injured ribs either above or below the diaphragm. Let's examine the rib-diaphragm relationships of an average-sized patient. First, posterior ribs one through eight are normally entirely above the diaphragm on full inspiration. Posterior ribs eleven and twelve are normally entirely below the diaphragm on full expiration or inspiration. Consequently, there is no difficulty with technique when you are X-raying these ten pairs of posterior ribs. Posterior ribs nine and ten normally appear below the diaphragm on full expiration, and should be radiographed in that position because shadows of lung markings are less of a problem.

Anterior ribs one through six are usually entirely above the diaphragm on full inspiration and should be radiographed in that position. Anterior ribs seven and eight are partially above and partially below the diaphragm on inspiration or expiration. Ribs nine and ten extend very little into the anterior portion of the chest, and those parts that do extend into the anterior portion are usually below the diaphragm. Ribs eleven and tweleve do not extend into the anterior chest at all. Anterior ribs seven through ten are visualized better below the diaphragm with full expiration.

The axillary portions of ribs one through eight should be radiographed in full inspiration above the diaphragm. Ribs nine and ten should be readiographed below the diaphragm on expiration.

As we previously mentioned, the above relationships are those of an average-sized patient. The level of the diaphragm is somewhat lower in a tall, thin patient and higher in a short, heavy patient. For these two extremes, add or subtract one rib from the figures given above, depending upon the level of the diaphragm. For example, on an average-sized patient, X-ray axillary ribs one through eight above the diaphragm on inspiration and ribs nine and ten below the diaphragm on expiration. If the patient is short and heavy, you should X-ray axillary ribs one through seven above the diaphragm on inspiration and ribs eight through ten below the diaphragm on expiration. If the patient is tall and thin, X-ray axillary ribs one through nine above the diaphragm on inspiration and the tenth axillary rib below the diaphragm on expiration. Apply this same line of reasoning to the anterior and posterior ribs.

Rib projections. The projections required for the various ribs depend upon your radiologist. Usually, a standard PA chest is taken on all patients with rib injuries to rule out damage to the underlying lung structures.

Exercises (241):

1. **Why is the breathing technique used during rib radiography?**

2. **List three factors to remember when using the breathing technique.**

3. **Why should a PA chest be performed on a patient with a suspected rib fracture?**

Column A, below, is a list of ribs or groups of ribs in various-sized patients. Column B shows three different respiratory phase considerations with the corresponding location of the ribs. Match the respiratory phase and rib location in column B that you would use to X-ray the ribs in column A by placing the letter of the column B item in the appropriate space in column A. Each column B item may be used once or more than once.

Column A

Posterior Ribs

___ 4. Seven and eight (average patient).
___ 5. Eleven and twelve (average patient).
___ 6. Eight through ten (short, heavy patient).
___ 7. One through nine (tall, thin patient).
___ 8. Nine and ten (average patient).

Anterior Ribs

___ 9. Four through six (average patient).
___ 10. Seven through nine (short, heavy patient).
___ 11. Six and seven (short, heavy patient).
___ 12. Six and seven (tall, thin patient).
___ 13. Seven and eight (average patient).

Axillary Ribs

___ 14. Seven and eight (average patient).
___ 15. Nine (average patient).
___ 16. Seven (short, heavy patient).
___ 17. Eight (short, heavy patient).
___ 18. Eight and nine (tall, thin patient).

Column B

a. Inspiration (above).
b. Expiration (below).
c. Inspiration or expiration (below).

242. Given descriptions of selected PA chest radiographs or positions, evaluate them and determine if they were properly positioned; if they were not properly positioned, recommend corrective measures.

PA Chest. The PA projection of the chest is, no doubt, performed more often than any other single radiograph. You perform them on many patients who are not even sick, for example, as part of a routine physical. Because you perform so many of these examinations and also because the patients are in good physical condition, you may sometimes forget the importance of the PA chest.

We assume you already know the proper procedure for performing this examination. Therefore, we will base our discussion on quality control. You must be able to evaluate the radiograph and determine whether or not the patient is properly positioned.

Position of the shoulders. One of the most common errors made in performing the PA chest is failure to "rotate," "roll," or "push" the patient's shoulders forward. If this is not done, the scapulae are superimposed over the upper lateral lung fields. The superimposition can very well obscure a lesion or other abnormality.

Some technicians feel that, if an AP projection is made of the chest, as during a bedside examination, it is not necessary to consider the scapulae. This is not true. If the patient's condition permits, the shadows should be eliminted just as on the PA projection.

Rotation. Another common error made is failing to position the chest with the median plane perpendicular to the film. If the median plane is not perpendicular, some structures are hidden, some are distorted, and the true relationships between structures are not maintained.

To check for rotation of the chest, start with the sternoclavicular joints. They should appear the same. Rotation of the chest usually produces an asymmetrical appearance. In addition, one of the joints may be obscured by the spine; or if it is seen, it is superimposed over the spine. In this case the projection of the other joint is slightly lateral to its normal location with the visualization of the corresponding side of the manubrium. When this is the case, it is easy to determine the direction of the rotation. If the left joint is projected laterally, the patient's left side is rotated away from the film. The opposite rotation of the chest causes a similar appearance of the right sternoclavicular joint.

The location of the spinous processes of the vertebrae can also be used to check the rotation of the chest. Normally, they should appear in the center of the vertebrae. Since the processes are located on the posterior surfaces of the vertebrae, they move in the opposite direction of the rotation. Be sure to check several continuous vertebrae. The deviation of a single spinous process is not uncommon in a properly positioned chest.

Locating the heart shadow with respect to the spine is another factor that can show patient rotation on a PA chest. Normally, the right border of the heart, the right atrium, lies slightly to the right of the spine on the PA projection. If you can see the right spinal border without the heart superimposed, it can be an indication of chest rotation toward the left side. This is easy to understand if you visualize the heart located in the anterior chest and imagine rotating the chest into a slight right-anterior, oblique position. The heart obviously moves toward the patient's left side.

Inspiration. The number of ribs visualized above the diaphragm indicates the degree of inspiration by the patient during exposure. Some radiologists like to count anterior ribs, while others count posterior ribs. In either case, count them in the right hemithorax. Also, the particular portion of the rib must be entirely above the diaphragm.

When you count posterior ribs, be careful when you begin the count. The tendency is to miss the first rib and begin with the second. Most radiologists require nine posterior ribs or six anterior ribs as proof of a full inspiration chest.

Generally, problems with full inspiration chest films on adults are limited to obese patients. If they are allowed to inspire twice before the exposure, with the film made on the second inspiration, the degree of inspiration is usually greater.

Exercises (242):

1. A PA radiograph of the chest shows dense nonpathological shadows superimposed over the superolateral lung fields. What is the probable cause of the shadows?

2. The right sternoclavicular joint on a PA chest radiograph is projected to the right of the spine. The left sternoclavicular spine is not visualized. Does this chest appearance indicate improper positioning? If so, how should the position be corrected?

3. A PA chest radiograph shows a symmetrical appearance of the sternoclavicular joints. Is the chest properly positioned? If not, how should the position be corrected?

4. A PA chest radiograph shows the spinous processes of T1 through T7 shifted to the left. Specifically, what does the shift indicate? How should it be corrected?

5. The right border of the thoracic spine is clearly seen without the superimposition of the heart on a PA radiograph of the chest. Does this indicate rotation? If so, how should the position be changed to correct the rotation?

6. A PA radiograph of the chest shows eight posterior ribs projected above the diaphragm. Is this a good inspiratory film? If not, how many posterior ribs should be seen?

7. A PA radiograph of the chest shows five anterior ribs above the diaphragm. Is this a good inspiratory film? If not, how many anterior ribs should be seen?

CHAPTER 6

Positioning of the Skull

WHILE IT IS relatively easy to produce diagnostic radiographs of many parts of the body, the skull and its contents present some problems not encountered with other body structures. Perhaps, the greatest reason for the problems is that the skull must be positioned precisely. There is not as much margin for error. If, for example, the rotation of skull is off as little as 5°, the structure under study may not be demonstrated on the radiograph. You must be "on the money," so to speak, to produce consistent diagnostic radiographs of the skull and its contents.

It is not practical to present in this CDC the seldom-used projections of the skull. They are available in commercial publications found in most Air Force hospitals. We will present most of the projections that are used every day. These are the six basic skull projections; the positions of the mastoids, petrous ridges, and internal auditory meati; the optic foramina; the zygomatic arches; the nasal bones; and the temporomandibular joints. We will begin with the six basic skull projections.

6-1. Basic Projections of the Skull

The six basic skull projections are: lateral, PA, AP, Waters', submentovertical, and verticosubmental. These projections are used to demonstrate many different structures and are performed frequently, as you know. Normally, the basic position is the same, regardless of the structure examined.

243. In a hypothetical situation, specify how you should position the patient for various lateral projections of the skull, and answer key questions about performing lateral projections.

Lateral Projection. Perhaps, you have noticed on occasion that cross-table lateral projections of the skull usually demonstrate the skull in the true lateral position. This is understandable because, with the patient in the supine position, it is relatively easy to adjust his head so that the median plane is parallel with the vertical X-ray film.

Most lateral projections, as you know, are performed with the patient in the semiprone position, and it is with this position that some technicians have problems. The problems usually stem from two factors. First, it is almost impossible to position some patients properly without elevating the head on some radiolucent material or elevating the patient's chest and shoulders so that the cervical spine is parallel with the film. Second, it is difficult for some technicians to "eyeball" the skull and determine whether it is in the proper position.

So that you can better understand how to cope with these problems, we should first define four improper skull positions.

a. Anterior or posterior rotation. The skull is rotated so that the face is either too close to, or too far away from, the table (see fig. 6-1).

b. Superior or inferior longitudinal angulation. The skull is tilted so that the top of the head is either too close to, or too far away from, the table (see fig. 6-2). Usually, with a thin patient, the top of the head is tilted away from the table, and, with an obese patient, it is tilted toward the table.

It is easier to prevent longitudinal angulation of the head than to prevent anterior or posterior rotation. The reason for this is that there are two simple ways to check the position. One is to use a rectangular piece of cardboard 3" x 8". Lay the longer edge of the cardboard on the table in front of the face and check the upper edge with the median plane. Adjust the position of the head until the upper edge of the cardboard is parallel with the median plane, as shown in figure 6-3. It is helpful to have on hand several pieces of cardboard of different widths because it is easier to check the alignment if the upper edge of the cardboard is the same height as the median plane. You may have to elevate the top portion of the head or elevate the patient's chest and shoulders to achieve the correct position.

Another way to check the longitudinal position of the head is to stand the cardboard on end and see if the interpupillary line is vertical with respect to the longitudinal plane of the table, as shown in figure 6-4. If not, correct the position of the head. To check the position of the head with respect to anterior or posterior rotation, position yourself at the end of the X-ray table and check the position of the head using the same piece of cardboard, as seen in figure 6-5. Rotate the head until the median plane is parallel with the table. Remember, you must check the head for anterior or posterior rotation from this position.

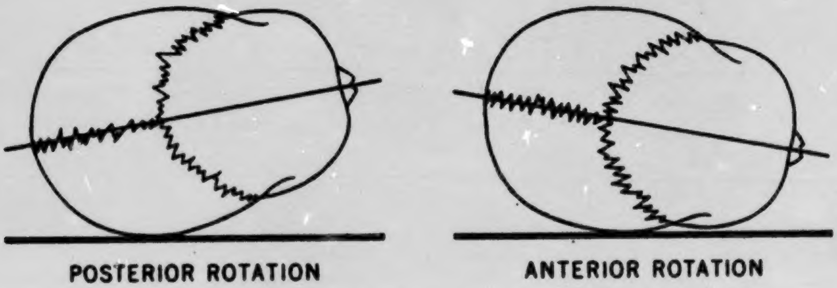


Figure 6-1. Anterior and posterior rotation of the lateral skull.

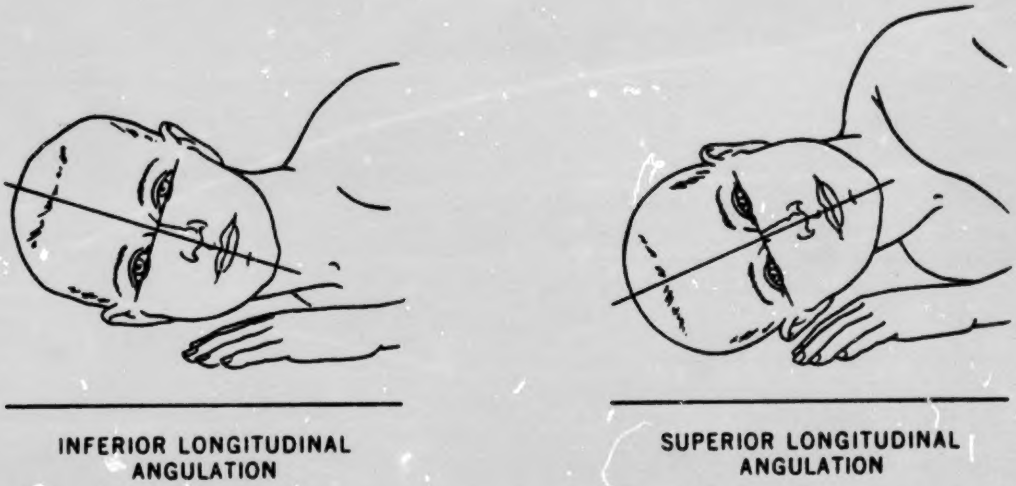

INFERIOR LONGITUDINAL ANGULATION
SUPERIOR LONGITUDINAL ANGULATION

Figure 6-2. Superior and inferior longitudinal angulation of the lateral skull.

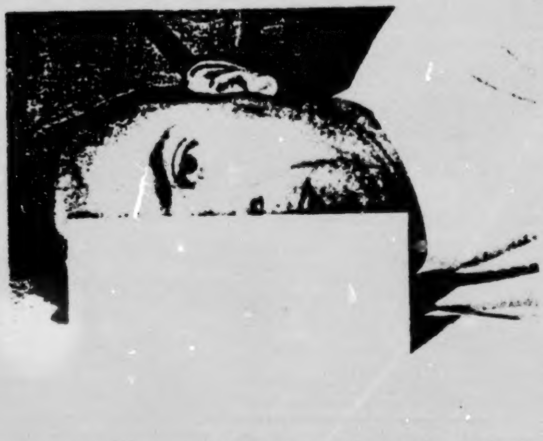


Figure 6-3. Photograph demonstrating the use of a rectangular piece of cardboard to align the median plane of the skull parallel with the film.

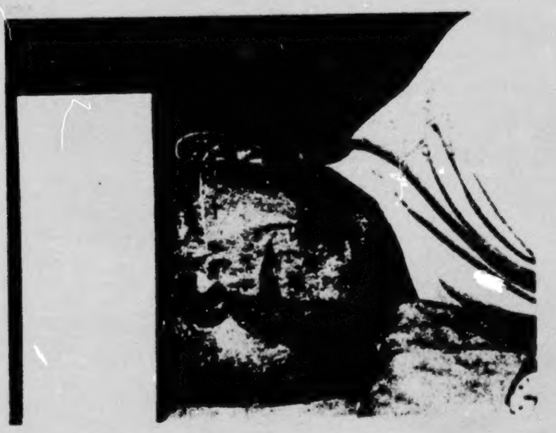


Figure 6-4. Photograph demonstrating the use of a rectangular piece of cardboard to align the interpupillary line perpendicular to the film.

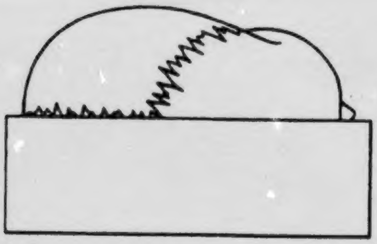


Figure 6-5. Photograph demonstrating the use of a rectangular piece of cardboard to align the median plane of the skull parallel with the film.

Center the midpoint of the film and direct the CR to the sella turcica if the examination is for nontraumatic reasons. This is very important because the radiologist may have difficulty evaluating the sella turcica if it is projected with divergent rays. The sella is located at a point three-quarters of an inch anterosuperiorly to the external auditory meatus. For trauma, center the film and direct the CR to the center of the skull. Many radiographs of the skull and facial bones are made with the head in the true lateral position. Four examples are as follows:

(1) Sella turcica—use a small cone field.

(2) Sinuses—center the midpoint of the film and the CR to the outer canthus of the eye—take all sinuses with the patient erect to demonstrate fluid levels.

(3) Nasal bones—take both laterals.

(4) Facial bones—center the film to the zygoma.

Exercises (243):

Below in column A are listed the true lateral and four near lateral position of the skull. In column B are listed five descriptions of the median plane of the skull. Match the description in column B with the position in column A by placing the letter of the column B item in the appropriate space in column A. Each column B item may be used once.

Column A

___ 1. True lateral.
___ 2. Anterior rotation.
___ 3. Posterior rotation.
___ 4. Superior angulation.
___ 5. Inferior angulation.

Column B

a. Parallel with the table.
b. Superior portion farther from table.
c. If extended, intersects with table above the top of head.
d. Anterior portion nearer the table.
e. If extended, intersects with table behind head.

6. What positioning errors are you most likely to make when you are aligning the skull for the lateral? What errors are you least likely to make? Why?

7. In your own words, explain how you should position the skull in the true lateral position. Be specific. Tell what you would check and how you would go about it.

8. If the history on the X-ray request said "headaches," where should the CR be directed for the lateral skill? Why?

9. For a lateral projection of the sinuses, where is the film centered and to what point is the CR directed?

10. Name four examinations, other than a regular skull radiograph, that require the skull to be positioned in the true lateral position.

244. Given a list of six pairs of structures demonstrated on a lateral projection of the skull, indicate whether they can show anterior or posterior rotation, superior or inferior longitudinal angulation, or both.

To check the lateral radiograph of the skull for the true lateral position, there are several bony structures to look for. Refer to figure 6-6 as we discuss them. The orbital plates of the frontal bone and the lesser wings of the sphenoid bone appear on the radiograph as solid, dense lines extending from behind the frontal sinuses to just anterior to the sella turcica. These dense lines should appear superimposed over each other when the skull is in the true lateral position. If they are separated, the skull is angled longitudinally.

The anterior borders of the middle fossa (the greater wings of the sphenoid) should also appear suprimposed over each other. If not, the skull is rotated anteriorly or posteriorly. These borders appear as a curved, dense line extending superoinferiorly about 1 inch anterior to the sella turcica.

The bilateral anterior and posterior clinoid processes of the sella turcica also should be superimposed. Depending on the direction of the

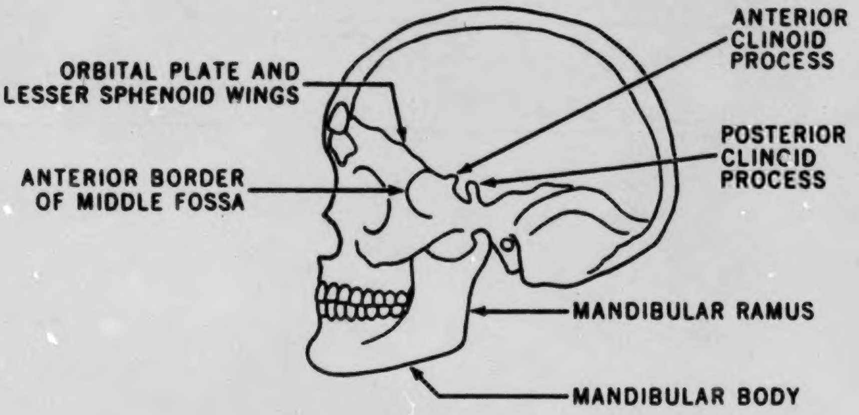

ORBITAL PLATE AND LESSER SPHENOID WINGS
ANTERIOR BORDER OF MIDDLE FOSSA
ANTERIOR CLINOID PROCESS
POSTERIOR CLINCID PROCESS
MANDIBULAR RAMUS
MANDIBULAR BODY

Figure 6–6. Lateral projection of the skull.

displacement, they can indicate anterior or posterior rotation or longitudinal angulation of the skull.

The mandible can also help you determine if rotation or longitudinal angulation is present. Keep in mind that longitudinal rotation of the skull may be present on the radiograph even though the mandibular rami are superimposed over each other. Also, anterior or posterior rotation may be present and the mandibular bodies may be superimposed over each other. In both cases, however, the second of the two mandibular parts will not appear superimposed.

Exercises (244):

Match the description of an improperly positioned lateral skull in column B with the bony structures that can be used to confirm the position in column A. Place the letter of the column B item in the appropriate space in column A. Each column B item may be used once or more than once.

Column A

___ 1. Posterior clinoid processes.
___ 2. Mandibular bodies.
___ 3. Anterior borders of the middle fossa.
___ 4. Anterior clinoid processes.
___ 5. Orbital plates of the frontal bone and lesser sphenoid wings.
___ 6. Mandibular rami.

Column B

a. Anterior or posterior rotation.
b. Superior or inferior longitudinal angulation.
c. Both a and b above.

245. Answer key questions about the structures demonstrated by PA projections of the skull and the procedures for performing these projections; differentiate between the appearance of the Caldwell's and the straight PA projection.

PA Projection. One PA (Caldwell) projection is taken to demonstrate several bony structures of the skull. Among them are the upper two-thirds of the orbits, the frontal and temporal bones, the anterior ethmoidal sinuses, the frontal sinuses, and the greater and lesser wings of the sphenoid bone, which are projected in the upper third of the orbits. The petrous ridges are projected to the level of the lower margins of the orbits. The projection is also used as a general survey radiograph.

Caldwell's projection is made with the patient prone with the skull in the PA position. Flex or extend the head so the orbitomeatal line is perpendicular to the table. It is usually more comfortable for the patient if you elevate his chest slightly. Normally, a 15° caudal CR is used for this projection, though some radiologists prefer a few degrees more. If the frontal bone is the main area of interest, direct the CR perpendicularly to the film. If this is the case, the radiograph is called a straight PA projection. The straight PA projection demonstrates the petrous ridges superimposed over the lower three-fourths of the orbits.

Exercises (245):

1. Name several structures demonstrated by Caldwell's projection.

2. Differentiate between the appearance of the orbits in Caldwell's projection and in the straight PA projection of the skull.

3. What CR angle and direction should be used for Caldwell's projection?

4. Give one instance when you should use a vertical CR for the PA projection?

5. How do you determine the amount of flexion extension of the head for both the straight PA and Caldwell's projections?

246. Name six structures demonstrated by the Chamberlain-Towne's (angled CR) projection of the skull, and specify the correct CR angulation and direction, or projection, to be used in demonstrating specific structures.

AP Projection. One AP (Chamberlain-Towne) projection is taken to demonstrate the occipital bone, the posterior portion of the parietal bones, the petrous ridges, the posterior portion of the foramen magnum, as well as other structures. It is especially useful in diagnosing fractures of the base of the skull. Depending upon the specific anatomy to be demonstrated and the radiologist's preference, the caudal CR varies from 30° to 60°. Usually, to demonstrate the structures mentioned above, the tube is angled 30° to 35°. To demonstrate the entire foramen magnum and jugular foramina, angle the CR 50° to 60°. This greater CR angle also can show basilar skull fractures.

When we speak of the tube angle for this projection, we actually mean the angle formed by the CR and the orbitomeatal line. The standard position of the head for this projection requires the orbitomeatal line to be perpendicular to the film. When such is the case, we can say that the specific CR angle used is a certain number of degrees from vertical. At times, however, it is not possible to position the orbitomeatal line perpendicular to the film because of the patient's condition. These situations require a compensatory adjustment of the CR.

Sometimes an AP projection of the skull is taken with the orbitomeatal line and the CR vertical (straight AP). This projection is used to demonstrate the posterior portion of the cranial vault only. It does not demonstrate the inferior portion of the occipital bone and consequently, may not demonstrate a basilar skull fracture.

Exercises (246):

1. Name six structures (or pairs of structures) demonstrated by Chamberlain-Towne's (angled CR) projection of the skull.

2. If the skull is in the standard AP position, what CR angulation and direction should be used to demonstrate the petrous ridges? To demonstrate the foramen magnum?

3. If the head is extended 10° beyond the point where the orbitomeatal line is vertical, what CR angulation should be used to demonstrate the jugular foramina? To demonstrate the posterior portion of the foramen magnum?

4. Name and describe the projection used to demonstrate the posterior portion of the cranial vault.

5. What projection described in the text should not be used to demonstrate a basilar skull fracture?

247. Name the sinuses and other structures demonstrated by Waters' projection of the skull and answer key questions about the procedures for making Waters' projection.

Waters' Projection. Waters' projection of the skull demonstrates most of the facial bones, the orbits, the maxillary sinuses, the frontal and ethmoidal sinuses, and various other structures. It is the best position for demonstrating the maxillary sinuses and, while the ethmoidal and frontal sinuses are somewhat distorted, they are fairly well seen.

One of the most common errors made in positioning the patient is the improper alignment of the orbitomeatal line. If you have a commercial device for checking the angle formed by the orbitomeatal line and the table, it is not too difficult to obtain the required 37°. If no commercial device is available, you can cut a piece of cardboard like the one shown in use in figure 6-7. Place it alongside the patient and flex or extend the head until the upper border of the cardboard is parallel with the orbitomeatal line. This device eliminates guesswork on your part by precisely aligning the orbitomeatal line. It is not good practice to perform this projection without a device such as we have described.

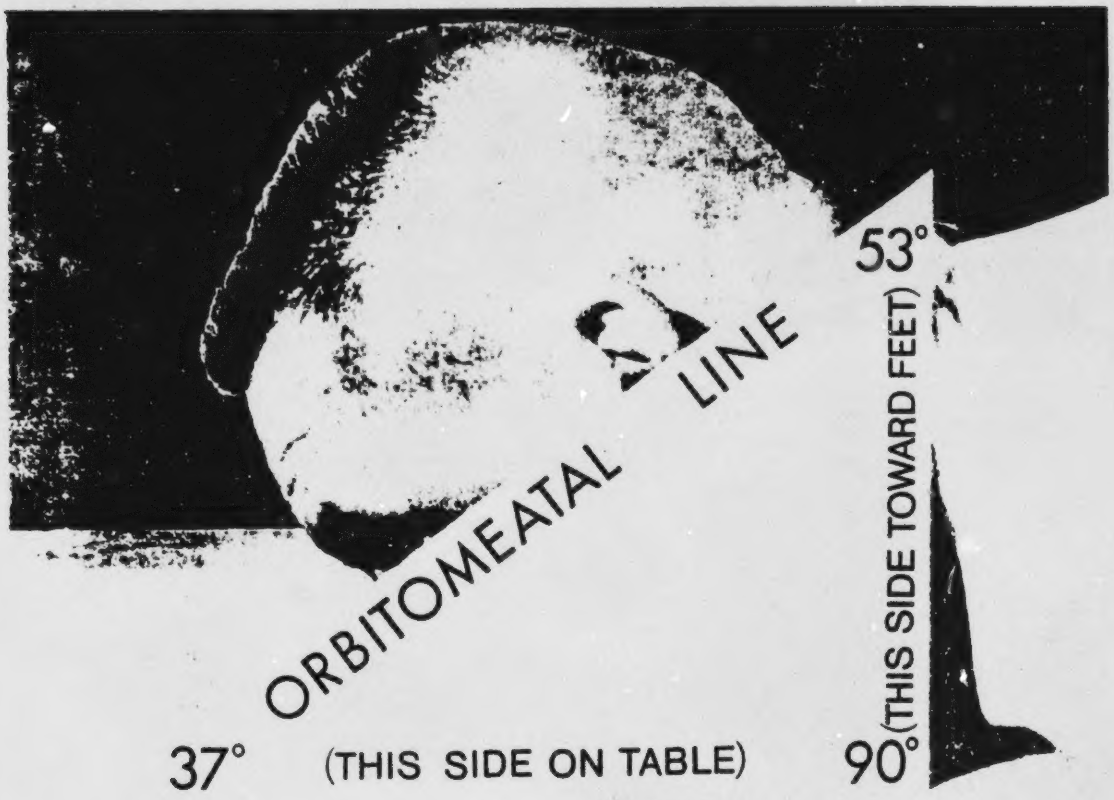


Figure 6-7. Waters' projection of the skull showing the use of a cardboard triangle to achieve the 37° angle formed by the orbitomeatal line and table.

Exercises (247):

1. What sinuses are best demonstrated by the Waters' projection?

2. Name some other structures demonstrated by Waters' projection.

3. Of what significance is 37° in Waters' projection?

4. Without referring to figure 6-7, describe the placement of the cardboard triangle alongside the patient's head.

248. Name eight structures demonstrated by the verticosubmental or submentovertical projections of the skull, compare the demonstrations obtained by the two projections, and answer key questions about the procedures.

Submentovertical and Verticosubmental Projections. The submentovertical and verticosubmental projections (also called basal projections) are used to demonstrate various structures of the skull and facial bones. Among them are the sphenoid and ethmoid sinuses, external and internal auditory meati, mastoid areas, base of the skull, mandible, and zygomatic arches.

The structures are best demonstrated if the patient is positioned so that the infraorbitomeatal line is parallel with the film. Depending upon the patient's ability to cooperate, it is sometimes difficult to achieve this position with the submentovertical projection and almost impossible with the verticosubmental projection. Direct the CR perpendicularly to the infraorbitomeatal line in all cases.

Use the seated position when performing a submentovertical projection, because it is easier to achieve the desired position of the head, and it is usually more comfortable for the patient (see fig. 6-8). If you use the recumbent position, elevate the trunk on pillows or pads. Figure 6-9 shows the verticosubmental projection.

Exercises (248):

1. Name eight structures or pairs of structures that are demonstrated by the verticosubmental or submentovertical projections of the skull.

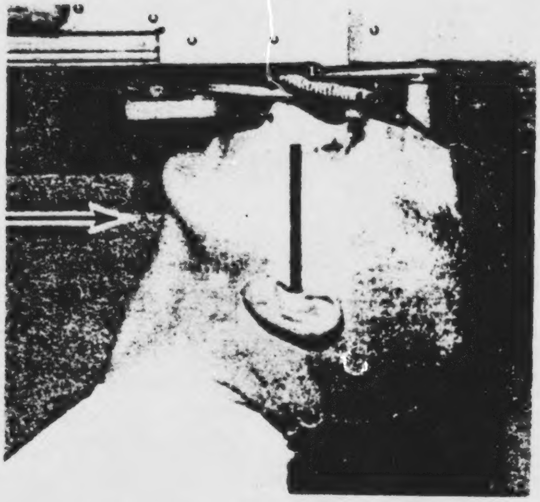


Figure 6-8. Submentovertical projection of the skull (seated position).

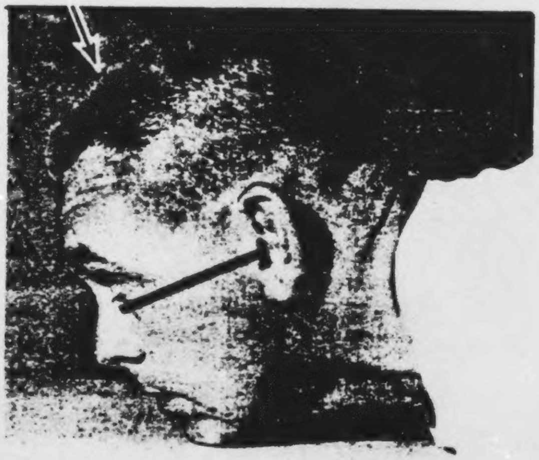


Figure 6-9. Verticosubmental projection of the skull.

2. Which of the two projections discussed in the text best demonstrates the structures in exercise #1 above?

3. How should the submentovertical projection be accomplished and why?

4. What is the CR-orbitomeatal line relationship for all basilar projections?

6-2. Mastoids and Internal Auditory Canals

There are many projections that demonstrate the mastoids and internal auditory canals. Some of the basic projections of the skull, such as Chamberlain-Towne's and the submentovertical already discussed, demonstrate them and are used in various departments. In addition to the basic skull projections, we will discuss Law's, Stenvers', Arcelin's, Mayer's, and Schuller's projections.

249. Give some significant features about the techniques for increasing details in the radiographs of the mastoids and internal auditory canals.

Standard Procedures. Before you study the specific projections, we should examine some standard procedures to follow with all "mastoid" projections. Always tape the patient's ears forward on oblique and lateral projections to prevent the superimposition of soft tissue shadow over the area under study. The structures are somewhat difficult to demonstrate in the first place and, even though the shadow cast by the ear is minimal, it is enough to reduce the detail.

The standard rule to cone down to the smallest field size possible is very important. Film fog due to excessive secondary and scatter radiation is particularly detrimental to film detail where such small structures as in the mastoid area are examined.

Use the small focal spot to provide better detail when possible. If the patient is comfortable in his position and you have his head properly immobilized, the longer exposure will not be a problem.

Some radiologists prefer to use medium or slow speed screens for these examinations to further increase detail. Since slower screens increase the radiation dose to the patient, they should be used only at the direction of the radiologist.

Exercises (249):

1. Why should the patient's ears be taped forward for oblique and lateral projections?

2. A cone field of what relative size should be used and why?

3. When can you use a small focal spot and the resultant long exposure?

4. Should you decide what type of screens to use? If not, who should?

250. Given selected statements pertaining to the three Law's projections, match each with the specific projection to which it relates.

Law's Projection. There are three different methods for performing Law's projection. All three demonstrate basically the same structures and the particular method used in your department depends upon your radiologist's preference.

The first projection, which we will call the "tube-tilt" projection, is made with the head in the true lateral position. Adjust the head so that the infraorbitomeatal line is parallel with the long axis of the film on all Law's projections. Angle the CR 15° toward the feet and 15° toward the face (see fig. 6-10). Direct the CR to a point about two inches superior to, and two inches posterior to, the external auditory meatus farthest from the film. The CR should exit from the skull at the lower mastoid process. This projection should not be taken with a grid because the 15° angle toward the face is across the lead strips and causes considerable grid cutoff. Consequently, the use of a small cone field to reduce secondary and scatter radiation takes on added significance.

The second projection, which we will call the "combination tube-tilt, part-rotation" projection, is made with the CR angled 15° caudad and the face rotated 15° toward the table (see fig. 6-11). The angle of the part eliminates the requirement to angle the tube toward the face. It also permits the use of a grid, since the CR is not directed across the lead strips as in the basic projection. This position is also a little more comfortable for the patient than the tube-tilt projection because the head is in a more natural, relaxed position, preventing part motion on the radiograph.

The third projection, which we will call the "part-rotation" projection, is made with the CR vertical and the head rotated 15° toward the face and tilted 15° longitudinally toward the feet, as seen in figure 6-12. This position is the most confortable of the three for the patient. Obviously, the vertical CR presents no grid cutoff problems.

Exercises (250):

Match the Law's projection in column B with the appropriate statement in column A by placing the letter of the column B projection in the appropriate space in column A. Each column B item may be used once or more than once.

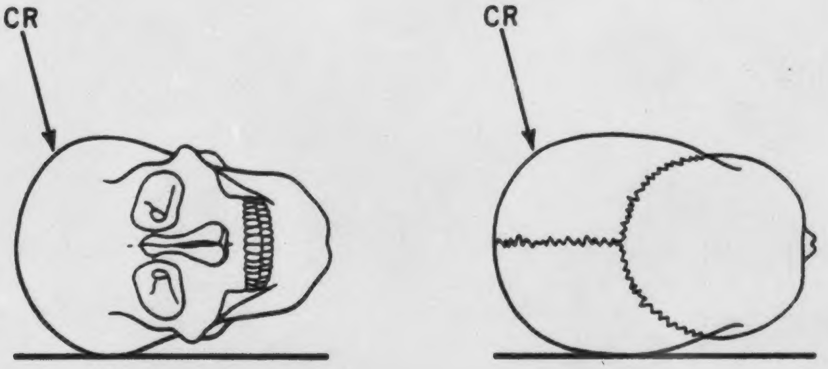


Figure 6-10. Law's "tube-tilt" projection.

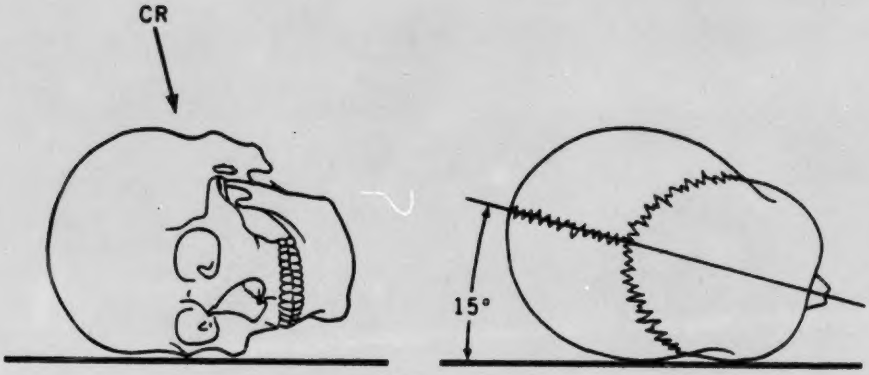


Figure 6-11. Law's "combination tube-tilt, part-rotation" projection.

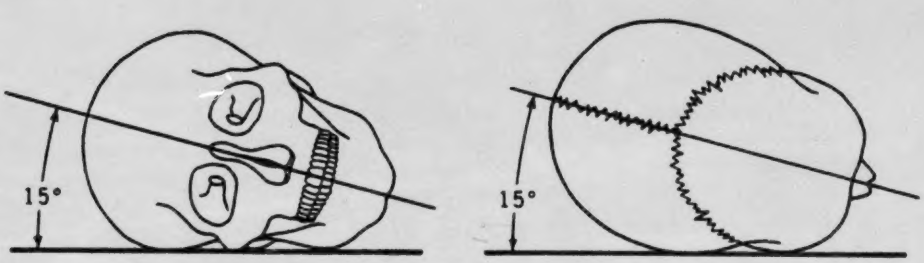


Figure 6-12. Law's "part-rotation" projection.

Column A

___ 1. Vertical CR.
___ 2. Do not use a grid.
___ 3. Small cone field most important.
___ 4. CR angled 15° caudad.
___ 5. Face rotated 15° toward table.
___ 6. Double angle of head.
___ 7. Tube angled 15° caudad and 15° toward face.
___ 8. Most comfortable for patient.
___ 9. Least comfortable for patient.

Column B

a. Tube-tilt method.
b. Combination tube-tilt, part-rotation method.
c. Part-rotation method.

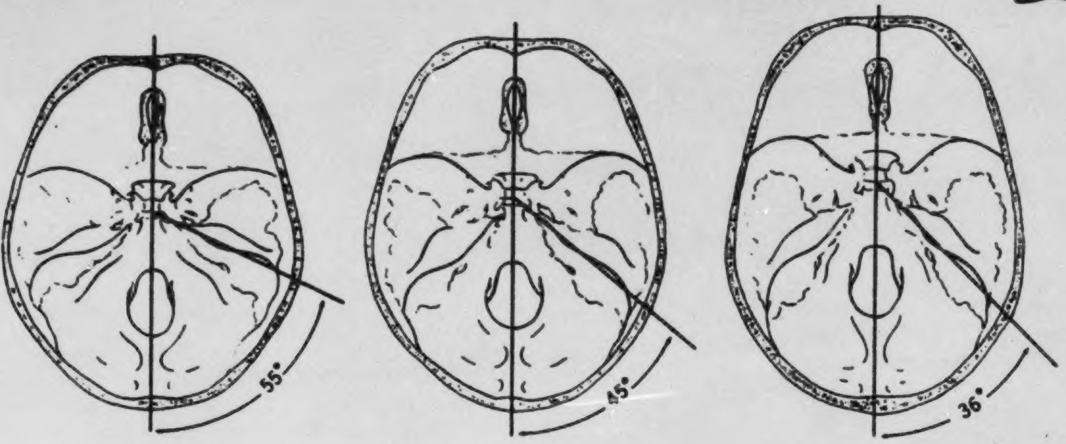
251. Given descriptions of hypothetical clinical situations requiring Stenvers' and Arcelin's projections, answer selected questions about the position and procedures required.

Stenvers' and Arcelin's Projections. The Stenvers' and Arcelin's projections are similar in that they are made with the petrous ridge parallel with the film. Before we discuss the actual positions, first look at the petrous ridges as they are situated in the three types of skulls. Refer to figure 6-13 as you study.

Notice the overall shape of each skull. The brachycephalic skull is short from front to back and wide from side to side. Also, notice the angle that the petrous ridges form with the median plane—55°. The mesocephalic skull is the most common or average type with the petrous ridges forming a 45° angle with the median plane. The third and last skull type, the dolichocephalic, is long from front to back and narrow from side to side. The petrous ridges in this skull form the most acute angle, 36°, of the three.

As you can imagine, to place the petrous ridges parallel with the film, you must consider the type of skull with which you are dealing. In all cases, rotate the face to the left to examine the right petrous ridge and rotate the face in the opposite direction to demonstrate the left petrous ridge.

Now, back to the Stenvers' and Arcelin's projections. Both are made with the head rotated so that the petrous ridge being examined is parallel with the film. Also, the infraorbitomeatal line is parallel with the transverse axis of the film for both projections. Stenvers' projection is made with the patient prone (PA projection) with the CR angled 12° cephalic. Place the patient in the supine position (AP projection) for the Arcelin projection and angle the tube 10° caudad.



BRACHYCEPHALIC MESOCEPHALIC DOLICHOCEPHALIC

Figure 6-13. The types and shapes of skulls, showing the angles formed by the median plane and petrous ridges.

Exercises (251):

A patient with a brachycephalic skull requires a repeat Arcelin's projection of the right petrous ridge. Based on the information in the text, answer exercises 1 through 4 below.

1. Is the projection PA or AP?

2. What is the CR angulation and direction?

3. In what direction is the face rotated?

4. How many degrees is the head rotated?

A patient with a mesocephalic skull requires a repeat Stenvers' projection of the left petrous ridge. Based upon the information presented in the text, answer exercises 5 through 8 below.

5. Is the projection PA or AP?

6. What is the CR angulation and direction?

7. In what direction is the face rotated?

8. How many degrees is the head rotated?

A patient with a dolichocephalic skull requires Stenvers' projections of both petrous ridges. Based upon the information presented in the text, answer exercises 9 through 12.

9. In which direction is the face rotated to radiograph the right petrous ridge?

10. In which direction is the face rotated to radiograph the left petrous ridge?

11. How many degrees is the head rotated to demonstrate the left petrous ridge?

12. How many degrees is the head rotated to demonstrate the right petrous ridge?

252. Given a list of characteristics pertaining to Mayer's or Schuller's projections, match each with the appropriate projection.

Mayer's and Schuller's Projections. Mayer's projection is made with the patient supine. Position the head so that the face is rotated 45° toward the mastoids under study. Flex the chin so that the infraorbitomeatal line is parallel with the transverse axis of the film. Direct the CR through the external auditory meatus of the side (lower) being examined, at an angle of 45° caudad.

For Schuller's projection, place the head in the true lateral position. Flex the chin so that the infraorbitomeatal line is parallel with the transverse axis of the film. Direct the CR 25° caudally through the external auditory meatus of the side nearest the film (the side being examined).

Exercises (252):

Match the projection in column B with the characteristic in column A by placing the letter of the column B projection in the appropriate space in column A. Each column B item may be used more than once. In addition, both column B items may apply to a single characteristic in column A.

Column A

___ 1. Lateral.
___ 2. CR 25° caudad.
___ 3. Oblique.
___ 4. Infraorbitomeatal line parallel with transverse axis of film.
___ 5. CR 45° caudad.
___ 6. 45° rotation of head.
___ 7. Side being examined is nearest the film.

Column B

a. Mayer's.
b. Schuller's.

6-3. Optic Foramina, Zygomatic Arches, and Nasal Bones

In this last section of your volume, we will emphasize some special procedures and significant points in the performance of projections of optic foramina, zygomatic arches, and nasal bones.

253. Compare the PA and AP Rhese projections of the optic foramina as to their demonstration of the optic foramen and the degree and direction of the rotation of the patient's head.

Optic Foramina. Rhese's projection of the optic foramina is usually made with the patient prone. It can be made with the patient supine if he cannot assume the prone position. If this is the case, there is an increase of about 2 inches in the part-film distance and resultant magnification on the radiograph.

To perform Rhese's projection (PA) have the patient rest his head on the nose and the zygoma and chin of the side under study. Rotate the posterior portion of the head toward the side under study until the median plane forms a 53° angle with the plane of the film or a 37° angle with a vertical plane. Adjust the head until the acanthiomeatal line is perpendicular to the plane of the film. Center the film to the inferolateral quadrant of the lower orbit. Direct a vertical CR to the center of the film (see figure 6-14).

With the patient supine, the AP projection is made in the same way. The main differences between the two projections is the magnification mentioned earlier. With the patient supine, the posterior portion of the head is also rotated toward the side under study.

Exercises (253):

1. Which projection, PA or AP, shows the optic foramen magnified and why?

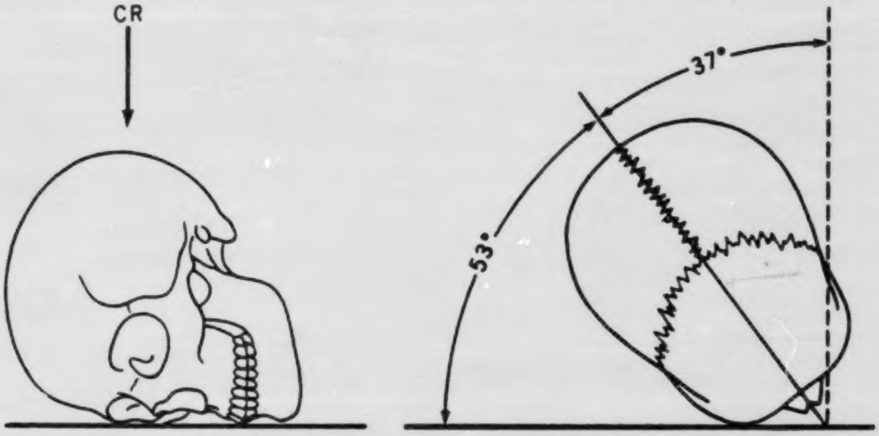


Figure 6-14. The Rhese projection of the optic foramina.

2. If you are using PA projections of the optic foramina, how many degrees and in what direction should the head be rotated for the left foramen?

3. If you are using AP projections of the optic foramina, how many degrees and in what direction should the head be rotated for the left optic foramen?

254. Given four line drawings representing radiographs of the optic foramina, evaluate them for the proper head position.

If the position is correct, the optic foramen appears in the approximate center of the lower, outer quadrant of the orbit. More than 53° rotation projects the foramen medially from the normal location and less than 53° rotation projects it laterally. Flexion of the head beyond the correct acanthomeatal-film relationship projects the foramen superior to the normal location. Overextension projects it inferior to the normal location.

Exercises (254):

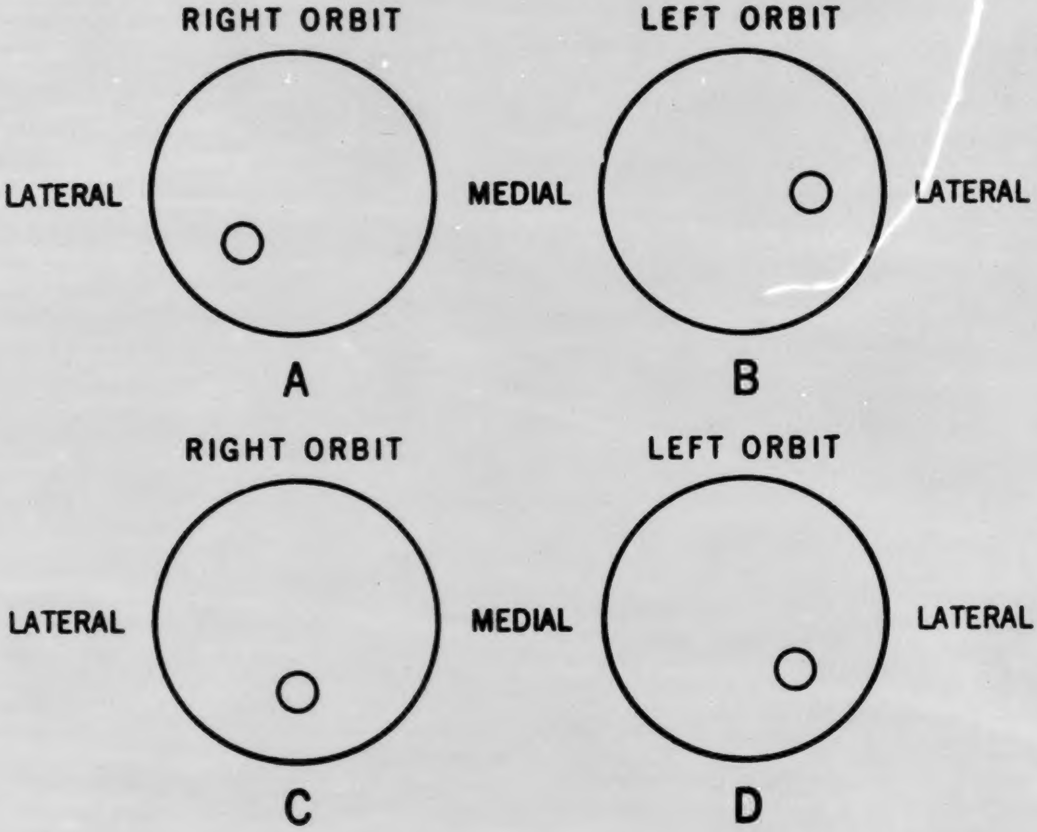


Figure 6-15. Objective 254, exercises 1 through 4.

Figure 6-15 represents line drawings of four optic foramina radiographs, with the circles inside the orbits representing the foramina. Indicate below in the appropriate space whether or not the position of the skull is correct. If not, describe how the position is "off."

1. Drawing A.

2. Drawing B.

3. Drawing C.

4. Drawing D.

255. Point out significant features of the procedure for radiographing the zygomatic arches.

Zygomatic Arches. You will recall that the submentovertical and verticosubmental (basal) projections demonstrate the zygomatic arches. At times, one of these projections reveals each zygomatic arch clear of superimposed structures and no further studies are required. Sometimes, however, the arches do not protrude enough from the side of the face to be visualized simultaneously on a basal projection. When this is the case, they should be radiographed one at a time.

To demonstrate the arches individually, use either the basic verticosubmental or the submentovertical projection. Tilt the top of the head about 15° away from the arch under study for both projections. We can also say "tilt the mandible toward the side under study." Notice that we said "tilt the head." This does not mean to rotate the head. To illustrate the difference refer to figure 6-16. Detail A is an inferior view of the skull. Detail B shows the skull rotated 15°. Notice that the relationships between the zygomatic arches and the skull do not change. Detail C shows the top of the head tilted 15° toward the right side. This movement throws the left zygomatic arch farther away from the side of the head allowing visualization of the entire structure without superimposition.

Be sure to direct the CR perpendicularly to the infraorbitomeatal line, which should be parallel with the film. The line is parallel with the zygomatic arch and if the CR-infraorbitomeatal line

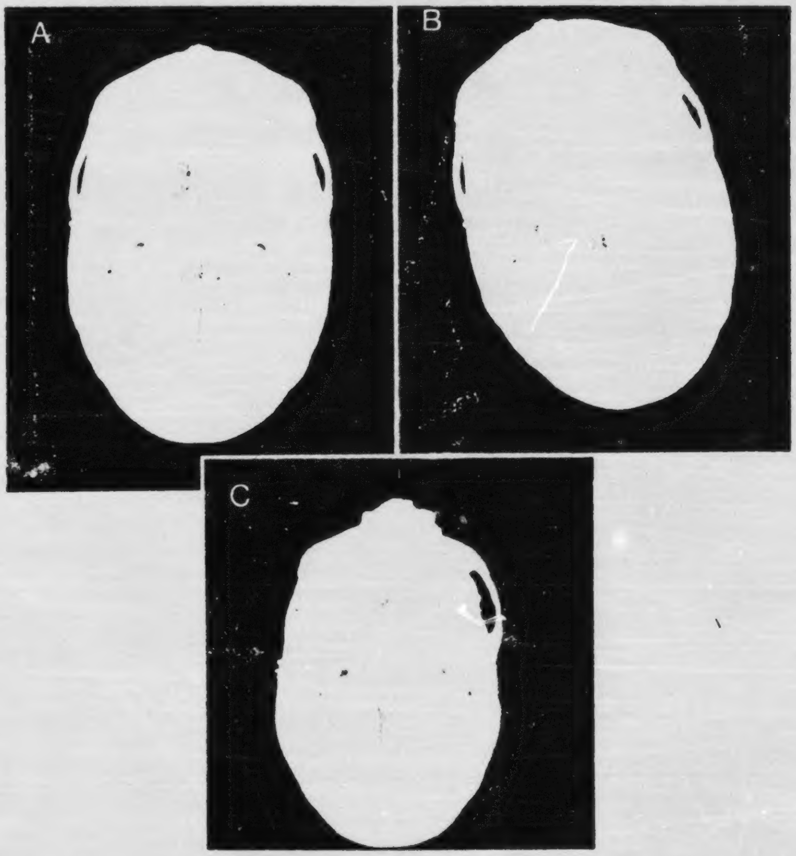


Figure 6–16. Inferior views of the skull showing the proper method to throw the zygomatic arch away from the skull.

relationship is not maintained, the arch will appear foreshortened on the radiograph. The best results are obtained if the head is adjusted so that the infraorbitomeatal line is parallel with the film. If the head is not adjusted and the CR is perpendicular to the infraorbitomeatal line, the zygomatic arch is elongated. This distortion must be tolerated at times, however, since some patients cannot achieve the desired position.

Exercises (255):

1. In your own words describe the movement of the head for radiographing the zygomatic arches one at a time.

2. How should the head be tilted for a submentovertical projection of the right zygomatic arch? For a verticosubmental projection of the right zygomatic arch?

3. How many degrees should the head be tilted to individually radiograph the zygomatic arches?

4. Why should the CR be directed perpendicularly to the infraorbitomeatal line?

5. If the infraorbitomeatal line-film relationship is not maintained, what is the effect on the radiograph? Is this effect sometimes acceptable? If so, under what conditions?

256. Give key factors in the procedure for the superoinferior projection and radiograph of the nasal bones.

Nasal Bones. Several projections are used to demonstrate the nasal bones. Some of them, such as Waters', Caldwell's, and the lateral, were discussed in another section of this chapter. Consequently, our discussion here will be limited to the superoinferior or axial projection.

This projection can be performed with the patient supine, prone, or erect (sitting). However, since the position of the patient's head is so critical, it is probably best to use the supine position because the position of the head is more easily maintained.

In order to project on the film the greatest number of nasal bones free from superimposition, direct the CR along a line from the glabella to the most anterior portion of the upper incisors. Both the CR and the imaginary line should be perpendicular to the film.

One way to set up the various relationships is to set the X-ray tube in the horizontal position first. With the patient supine, extend the head until the previously described imaginary line is also horizontal or parallel with the table. Insert an occlusal film in the patient's mouth and adjust it to the vertical position while maintaining the position of the head. Align the CR to the film along the imaginary line (see fig. 6-17).

The projection of the frontal bone anterior to the level of the upper incisors indicates overflexion of the head. Projection of the teeth anterior to the level of the frontal bone indicates overextension of the head. If the anterior portions of the upper incisors are exactly superimposed over the anterior portion of the frontal bone, no improvement can be made in the position regardless of the degree of nasal bone visualization.

Exercises (256):

1. What body position is recommended for the superoinferior projection? Why?

2. For the superoinferior projection, what is the relationship between the CR, an imaginary line between the glabella and anterior portion of upper incisors, and the film?

3. When you are checking the radiograph, what structures should you look for in evaluating the patient's position?

4. Describe the appearance of the structures indicated in exercise #3 above if the position is correct. If the head is improperly positioned.

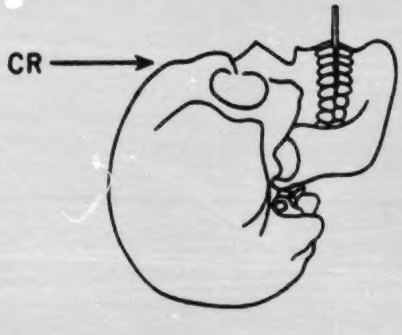


Figure 6-17. Superoinferior projection of the nasal bones with the patient in the supine position.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

200 - 1. T.
200 - 2. F. The ileum is distal to the jejunum.
200 - 3. T.
200 - 4. T.
200 - 5. F. The radius is lateral to the ulna.
200 - 6. T.
200 - 7. T.

201 - 1. b.
201 - 2. c.
201 - 3. a.
201 - 4. d.
201 - 5. a.

202 - 1. T.
202 - 2. F. The third toe has three phalanges.
202 - 3. F. The first toe has only two phalanges.
202 - 4. F. The base of the distal phalanx articulates with the head of the middle phalanx in the fourth toe.
202 - 5. T.
202 - 6. T.
202 - 7. T.
202 - 8. T.
202 - 9. F. Each metatarsal joins with another metatarsal.
202 - 10. T.
202 - 11. F. The first cuneiform is on the medial side.
202 - 12. F. The calcaneus is the largest tarsal bone.
202 - 13. T.
202 - 14. T.
202 - 15. T.
202 - 16. F. The sustentaculum is on the calcaneus.
202 - 17. F. There are 26 bones of the foot and toes.

203 - 1. Talus, tibia, and fibula.
203 - 2. Tibia.
203 - 3. Fibula.
203 - 4. They are important for weight bearing and mobility and attempts are made to maintain them during treatment of injuries.
203 - 5. Diarthrodial or hinge-type.

204 - 1. Tibia, fibula.
204 - 2. Fibula.
204 - 3. Medial malleolus.
204 - 4. Interosseous crest.
204 - 5. Superior articular surface, medial and lateral condyles, intercondylar eminence, tibial tuberosity.
204 - 6. On the tibial tuberosity.
204 - 7. Lateral malleolus.
204 - 8. Proximal.
204 - 9. On the fibular head.
204 - 10. The tibia.

205 - 1. b.
205 - 2. a.
205 - 3. c.
205 - 4. e.
205 - 5. d.
205 - 6. a.
205 - 7. b.

206 - 1. Linea aspera.
206 - 2. A triangular-shaped area on the posterior side of the distal femur.
206 - 3. Posterior.
206 - 4. Superior and medial.
206 - 5. Head.
206 - 6. Yes.
206 - 7. Fovea capitis.

207 - 1. T.
207 - 2. F. The iliac crest extends from the ASIS to the PSIS.
207 - 3. T.
207 - 4. T.
207 - 5. T.
207 - 6. F. The lesser sciatic notch is located on the ischium.
207 - 7. T.
207 - 8. T.
207 - 9. T.
207 - 10. F. The pubic arch is formed by the inferior ramus of the pubis and the ramus of the ischium.
207 - 11. T.
207 - 12. T.
207 - 13. T.
207 - 14. F. The sacrum and coccyx form the posterior margin of the true pelvis.

208 - 1. Five.
208 - 2. The first. The fifth.
208 - 3. Posterior.
208 - 4. The fifth lumbar.
208 - 5. The first coccygeal.
208 - 6. Ilia, sacroiliac joints.
208 - 7. An oval articular surface on the body of the first sacral vertebra.
208 - 8. Posteriorly.
208 - 9. Four.
208 - 10. Lines that mark the former separations of the coccygeal vertebrae.
208 - 11. Coccygeal cornua.
208 - 12. Base, apex.

209 - 1. Body, base, head.
209 - 2. The first (thumb).
209 - 3. Fourteen.
209 - 4. Middle phalanx, fourth digit.
209 - 5. Distal, proximal.
209 - 6. Fourth.
209 - 7. Distal.
209 - 8. Eight.
209 - 9. Greater and lesser multangulars, capitate, hamate.
209 - 10. Navicular, lunate, triangular, pisiform.
209 - 11. Pisiform.
209 - 12. Capitate.

210 - 1. a.
210 - 2. b.
210 - 3. b.
210 - 4. b.
210 - 5. a.
210 - 6. b.
210 - 7. b.

211 - 1. F. The olecranon fossa is on the posterior humerus.
211 - 2. T.
211 - 3. F. The radial fossa is on the lateral humerus.
211 - 4. F. The medial epicondyle is more prominent.
211 - 5. F. The deep depression is the olecranon fossa.
211 - 6. T.
211 - 7. F. The semilunar notch articulates with the trochlea.

211 - 8. F. The olecranon process fits into the olecranon fossa when the elbow is extended.

212 - 1. Surgical neck—the constricted portion of the humerus below the tuberosities.
212 - 2. Lesser tuberosity—bony eminence on the anterior surface.
212 - 3. Greater tuberosity—rounded eminence on the lateral side.
212 - 4. Bicipital groove—deep furrow between the tuberosities.
212 - 5. Anatomical neck—the portion that connects the head with the shaft.
212 - 6. Head—uppermost portion.

213 - 1. Sternal end, acromial end.
213 - 2. Coracoid tuberosity and costal tuberosity.
213 - 3. Subscapular fossa.
213 - 4. A projecting plate of bone that extends superlaterally from the vertebral border on the posterior side.
213 - 5. Above—supraspinatus fossa.
Below—infraspinatus fossa.
213 - 6. Superior border.
213 - 7. Inferior angle.
213 - 8. Acromion process.
213 - 9. Glenoid fossa.
213 - 10. Coracoid process.
213 - 11. Enarthrodial or ball and socket.
213 - 12. The head of the humerus and the glenoid fossa of the scapula.
213 - 13. The acromion process of the scapula and the distal end of the clavicle.

CHAPTER 2

214 - 1. Five.
214 - 2. Body.
214 - 3. Posterior to the sides of the vertebral body.
214 - 4. Lamina.
214 - 5. The superior articular processes of the fifth lumbar vertebra.
214 - 6. Spinous process.
214 - 7. Two.
214 - 8. Annulus fibrosus, nucleus pulposus.
214 - 9. Between the bodies of the vertebrae.
214 - 10. Apophyseal joints.
214 - 11. The fifth lumbar vertebra and the sacrum.

215 - 1. T.
215 - 2. F. Costal articular facets are only located on the transverse processes of T-1 through T-10.
215 - 3. T.
215 - 4. F. They are very much alike except for the articular facets.
215 - 5. T.
215 - 6. T.
215 - 7. F. Thoracic vertebrae have apophyseal joints.

216 - 1. Atlas.
216 - 2. Axis.
216 - 3. All.
216 - 4. Atlas.
216 - 5. Axis.
216 - 6. Seventh.
216 - 7. Bifid.
216 - 8. Occipital, atlanto-occipital.
216 - 9. Atlanto-axial.
216 - 10. Two.

217 - 1. True—14 ribs (7 pairs)—they are attached to cartilage that joins directly with the sternum.
217 - 2. False—6 ribs—(3 pairs)—they are attached to cartilage that does not join directly with the sternum.
217 - 3. Floating—4 ribs (2 pairs)—they do not articulate anteriorly with anything.

218 - 1. Manubrium.
218 - 2. The suprasternal or manubrial notch, and the clavicular notches.
218 - 3. Sternal angle, or angle of Louis.
218 - 4. Distal part.

219 - 1. d.
219 - 2. f.
219 - 3. e.
219 - 4. b.
219 - 5. a.
219 - 6. g.

CHAPTER 3

220 - 1. Frontal, parietals, occipital.
220 - 2. Frontal.
220 - 3. Supraorbital foramen.
220 - 4. Squamosal.
220 - 5. It is a vertical groove on the internal surface, formed by the fusion of the original two parts of the frontal bone.
220 - 6. Parietals.
220 - 7. Temporal.
220 - 8. Petrus ridges.
220 - 9. Mandibular fossa.
220 - 10. Temporal.
220 - 11. Foramen magnum.
220 - 12. Occipital condyles.
220 - 13. External occipital protuberance (EOP).
220 - 14. Sphenoid.
220 - 15. Optic foramina.
220 - 16. On the sella turcica.
220 - 17. Anterior and posterior clinoid processess.
220 - 18. Sphenoid.
220 - 19. Ethmoid.
220 - 20. Cribriform plate.
220 - 21. On the superior portion of the cribriform plate of the ethmoid.
220 - 22. Perpendicular plate.

221 - 1. c.
221 - 2. d.
221 - 3. i.
221 - 4. h.
221 - 5. f.
221 - 6. e.
221 - 7. a.

222 - 1. d.
222 - 2. a.
222 - 3. c.
222 - 4. b.
222 - 5. a.
222 - 6. d.
222 - 7. b.
222 - 8. c.

223 - 1. T.
223 - 2. T.
223 - 3. F. The antrum of Highmore is in the maxilla.
223 - 4. T.
223 - 5. F. The palatine processes form the anterior part of the roof of the mouth and the floor of the nasal cavity.
223 - 6. T.
223 - 7. F. The prominent portions of the cheeks are formed by the zygomatic bones.
223 - 8. T.
223 - 9. F. The zygomatic arches are formed by both the zygomatic and temporal bones.
223 - 10. T.
223 - 11. T.
223 - 12. F. The inferior nasal conchae are located along the lateral walls of the nasal cavity.
223 - 13. T.

223 - 14. T.
223 - 15. F. The symphysis is medially located with respect to the mental foramen.
223 - 16. F. There are two mental foramina.
223 - 17. F. The mandibular angle is located at the junction of the body and ramus.
223 - 18. T.
223 - 19. F. The condyloid process is posterior to the coronoid process.
223 - 20. F. The mandibular notch is located between the cornoid process and the condyloid process.

224 - 1. c.
224 - 2. c.
224 - 3. b.
224 - 4. d.
224 - 5. a.
224 - 6. d.

CHAPTER 4

225 - 1. No.
225 - 2. Articular surfaces of the interphalangeal joints.
225 - 3. Use a vertical CR.
225 - 4. Yes. Slightly elongated.
225 - 5. Yes.
225 - 6. Cuneiforms, cuboid, and navicular.

226 - 1. To demonstrate pes cavus and pes planus.
226 - 2. The radiologist assumes that the films were taken with equal weight distribution when he interprets the radiographs. If they are not, his diagnosis may be incorrect.
226 - 3. Stress to the patient the importance of equal weight distribution. Leave the patient in the same position for both radiographs.
226 - 4. The anterior portion.
226 - 5. To the level of the trochlear process and sustentaculum tali.
226 - 6. Flex the ankle so that the plantar surface of the foot is perpendicular to the film. Angle the CR 40° toward the head.
226 - 7. It will appear foreshortened, and less of it will be seen.

227 - 1. No. The AP and lateral projections do not project the entire lateral malleolus clear of overlying structures. A medial oblique should be performed.
227 - 2. Extension of the ankle. Flex the ankle joint as much as possible.
227 - 3. T.
227 - 4. F. The entire stress examination consists of the two AP stress projections plus one standard AP.
227 - 5. T.
227 - 6. T.

228 - 1. T.
228 - 2. F. The knee should be flexed only 45°. The angle formed by the leg and femur is 135°.
228 - 3. F. The width of the spaces between the femoral condyles and the tibial condyles should be checked.
228 - 4. F. The tunnel projection demonstrates the tibial intercondylar eminence and femoral intercondyloid fossa.
228 - 5. T.
228 - 6. T.
228 - 7. T.
228 - 8. T.
228 - 9. T.
228 - 10. F. You should rule out only a transverse fracture. The axial projection will rule out a vertical fracture.

229 - 1. First method—Palpate the most superior point of the greater trochanter and visualize a transverse plane through that point. Palpate the ASIS and visualize a sagittal plane 2 inches medial to it. Localize the head of the femur at the point where the two planes meet. Second method—Palpate the ASIS and upper margin of the symphysis pubis. Imagine a second line, perpendicular to the middle of first line. Localize the head of the femur 1 inch along the second line.

230 - 1. Palpate the ASIS and upper margin of the symphysis pubis. Imagine a line connecting them. Imagine a second line bisecting and perpendicular to the first line. The second line represents the long axis of the femoral neck.
230 - 2. To prevent "guessing" at the tube-part-film alignment.
230 - 3. Three inches from the ASIS-to-symphysis line.
230 - 4. Don't rotate or otherwise move the leg.
230 - 5. To reduce film fog.

231 - 1. The joint spaces are at an angle to the film.
231 - 2. No.
231 - 3. Superimposed over each other.
231 - 4. No.
231 - 5. Yes.
231 - 6. The joint spaces are perpendicular to the film.
231 - 7. Clear and free of overlying structures.
231 - 8. The second one (using the step wedge). Because the articular surfaces will appear free of overlying structures and not superimposed over each other.

232 - 1. Volar, concavity.
232 - 2. Pisiform, triangular, capitate, hamulus process, and greater and lesser multangulars.
232 - 3. Vertical.
232 - 4. Forearm.
232 - 5. Hand, rotated, ulnar, hamulus process, pisiform.

233 - 1. A minor degree of pronation of the hand.
233 - 2. Place a sandbag across the patients' hand.
233 - 3. No. Elevate the forearm slightly.
233 - 4. No.
233 - 5. A fracture of the radial head. The radiograph will not show the radial head in the lateral position.
233 - 6. Place the hand in the lateral position.
233 - 7. Four, hand.
233 - 8. Too little rotation. Rotate the elbow 40° to 45°.
233 - 9. Too much rotation. Rotate the elbow 40° to 45°.
233 - 10. Radial head.

234 - 1. Neutral.
234 - 2. Internal.
234 - 3. External.

CHAPTER 5

235 - 1. No. The head is flexed beyond the point where the incisor-base line is perpendicular to the film. Extend the head until the imaginary line is perpendicular.
235 - 2. No. The head is extended beyond the point where the incisor-base line is perpendicular to the film. Flex the head until the imaginary line is perpendicular.
235 - 3. No the imaginery line is aligned as required, but the tongue is positioned too high in the mouth. Have the patient say "Ah" during the exposure to lower the tongue shadow below the atlas and axis.
235 - 4. Yes. (NOTE: Even though the two structures are superimposed over the atlas and odontoid process, they, the incisors and base, are in the same vertical plane. Consequently, this position is as good as it can be.)

236 - 1. To demonstrate the intervetebral foramina.
236 - 2. Left posterior oblique and right anterior oblique. Right posterior oblique and left anterior oblique.
236 - 3. Part rotation—45°; CR angulation—15° to 20° cephalic. Part rotation—45°; CR angulation—15° to 20° caudal.

236 - 4. Rotate the median plane of the skull slightly more than 45° from perpendicular.

237 - 1. The first film should be a cross-table lateral. Make it without moving the patient at all. The reasons for this action are to help determine whether the injury requires traction before moving the patient, and to determine the course of action for the remaining radiographs.
237 - 2. Take no action until the radiologist/physician tells you what he wants next.
237 - 3. No part rotation on this patient. Angle the CR 15° to 20° cephalic and 45° medially.
237 - 4. Remove the grid.
237 - 5. Discuss the movements needed with the radiologist/physician. Ask him to supervise the movements if possible. If he cannot remain, ask him for specific instructions on moving the patient.

238 - 1. Radiograph A.
238 - 2. Radiograph B.
238 - 3. Radiograph C.
238 - 4. Radiograph A.
238 - 5. The joints do not open at a 45° angle.
238 - 6. Right.
238 - 7. Right.

239 - 1. T.
239 - 2. F. The intervetebral spaces *should* be perpendicular to the film. They do not have to be. You can compensate by using an angled CR.
239 - 3. F. An angled CR is used with lumbar "sag" in which the long axis of the spine is not parallel with the film.
239 - 4. F. It is usually greater in female patients.
239 - 5. F. In some patients the spine is already parallel, and there is no "sag" in the recumbent position.
239 - 6. T.
239 - 7. T.
239 - 8. T.
239 - 9. F. Elevating the dependent leg helps prevent anterior rotation.

240 - 1. 70°. 110°.
240 - 2. Right.
240 - 3. Right posterior oblique.

241 - 1. To prevent the shadows of lung markings from obscuring a fracture.
241 - 2. Use an exposure long enough to cover two or three respiratory phases. Stress to the patient the need to breathe smoothly and otherwise hold perfectly still. Do not use the technique if the patient's breathing is labored.
241 - 3. To rule out damage to the lungs.
241 - 4. a.
241 - 5. c.
241 - 6. b.
241 - 7. a.
241 - 8. b.
241 - 9. a.
241 - 10. b.
241 - 11. b.
241 - 12. a.
241 - 13. b.
241 - 14. a.
241 - 15. b.
241 - 16. a.
241 - 17. b.
241 - 18. a.

242 - 1. The scapulae were not rolled forward during the examination.
242 - 2. Yes. Rotate the right side of the patient's chest back toward the film.
242 - 3. Yes, the chest is properly positioned.
242 - 4. Rotation in the left anterior oblique position. Rotate the right side of the patient's chest back toward the film.
242 - 5. Yes. Rotate the patient's left side back toward the film.
242 - 6. No. Nine.
242 - 7. No. Six.

CHAPTER 6

243 - 1. a.
243 - 2. d.
243 - 3. e.
243 - 4. c.
243 - 5. b.
243 - 6. Anterior or posterior rotation. Superior or inferior angulation. There are two ways to check the skull for longitudinal angulation and only one way to check for rotation.
243 - 7. Your answer to this exercise should reflect the importance of aligning the median plane parallel with the film. You should also use some type of device, such as the piece of cardboard, to help you align the skull, since, "eyeballing" the alignment is subject to error. In addition, you should mention the fact that you must check the alignment of the skull from two positions: in front of the patient's face, and at the end of the table above the top of the patient's head.
243 - 8. Three-fourths of an inch anterosuperiorly to the external auditory meatus. That is the location of the sella turcica and the sella must be projected with perpendicular rays (CR) to permit interpretation.
243 - 9. The outer canthus of the eye.
243 - 10. Sella turcica, sinuses, nasal bones and facial bones.

244 - 1. c.
244 - 2. b.
244 - 3. a.
244 - 4. c.
244 - 5. b.
244 - 6. a.

245 - 1. Upper two-thirds of the orbits, frontal and temporal bones, anterior ethmoidal sinuses, frontal sinuses, and wings of the sphenoid.
245 - 2. In Caldwell's, the greater and lesser wings of the sphenoid are projected in the upper third of the orbits. In the straight PA, the petrous ridges are projected over the lower three-fourths of the orbits.
245 - 3. 15° caudad or as specified by the radiologist.
245 - 4. When the examination is performed to visualize the frontal bone.
245 - 5. When the orbitomeatal line is perpendicular to the film, the flexion/extension is correct.

246 - 1. Occipital bone, posterior parietal bones, petrous ridges, foramen magnum, jugular foramen.
246 - 2. 30° to 35° caudad. 50° to 60° caudad.
246 - 3. 40° to 45°. 60° to 70°.
246 - 4. Straight AP with the orbitomeatal line and CR vertical.
246 - 5. Straight AP.

247 - 1. Maxillary.
247 - 2. Facial bones, orbits, frontal sinuses, and ethmoidal sinuses.
247 - 3. It is the angle formed by the orbitomeatal line and the table when the flexion/extension of the head is correct.
247 - 4. The triangle should be placed so that its shortest side is perpendicular to the table, the side opposite the 53° angle is flat on the table, and the hypotenuse parallels the orbitomeatal line.

248 - 1. Sphenoid and ethmoid sinuses, external and internal auditory meati, mastoids, base of the skull, mandible, and zygomatic arches.

248 - 2. Submentovertical.
248 - 3. With the patient seated. It is easier to place the infraorbitomeatal line parallel with the film and the position is more comfortable for the patient.
248 - 4. The CR is always perpendicular to the infraorbitomeatal line.

249 - 1. To prevent a loss of detail due to the shadow cast by the ears.
249 - 2. Small, to prevent loss of detail because of secondary radiation.
249 - 3. When the patient is comfortable and his head is properly immobilized.
249 - 4. No. The radiologist.

250 - 1. c.
250 - 2. a.
250 - 3. a.
250 - 4. b.
250 - 5. b.
250 - 6. c.
250 - 7. a.
250 - 8. c.
250 - 9. a.

251 - 1. AP.
251 - 2. 10° caudad.
251 - 3. To the left.
251 - 4. 35°.
251 - 5. PA.
251 - 6. 12° cephalic.
251 - 7. To the right.
251 - 8. 45°.
251 - 9. To the left.
251 - 10. To the right.
251 - 11. 54°.
251 - 12. 54°.

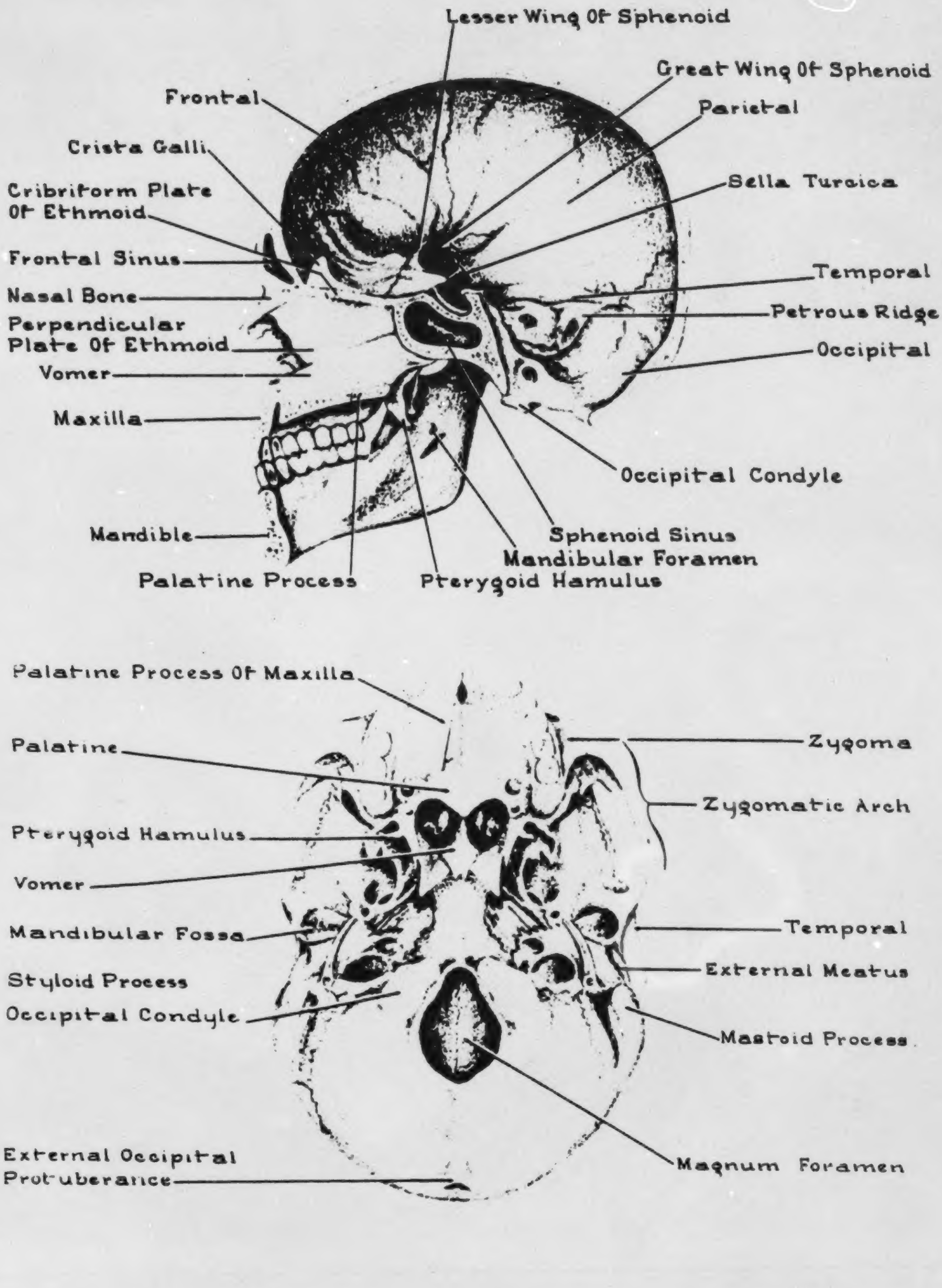
252 - 1. b.
252 - 2. b.
252 - 3. a.
252 - 4. a, b.
252 - 5. a.
252 - 6. a.
252 - 7. a, b.

253 - 1. AP. The foramen is farther from the film.
253 - 2. The head should be rotated so that the median plane forms a 53° angle with the plane of the film or a 37° angle with a vertical plane. For the left foramen rotate the posterior portion of the head to the left.
253 - 3. The head should be rotated so that the median plane forms a 53° angle with the plane of the film or a 37° angle with a vertical plane. For the right foramen rotate the posterior portion of the head to the right.

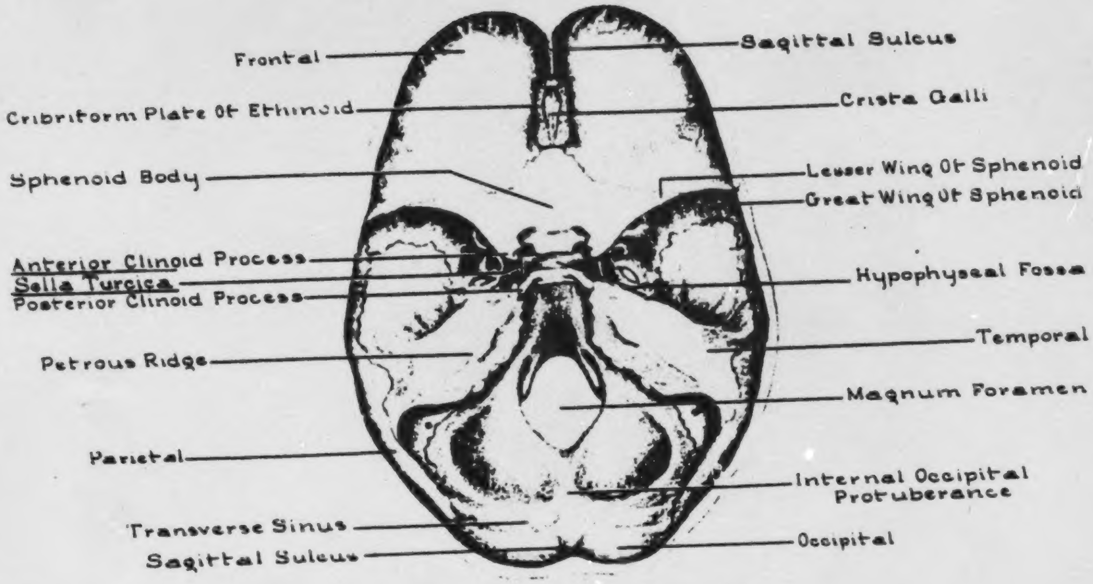
254 - 1. The position is correct—the optic foramen is projected in the lower outer quadrant of the orbit.
254 - 2. The position is incorrect—indicated by projection of the optic foramen above the normal location. The head is overflexed.
254 - 3. The position is incorrect—indicated by projection of the optic foramen medial to its normal location. The median plane forms an angle of more than 53° with the plane of the film.
254 - 4. The position is correct—the optic foramen is projected in the lower outer quadrant of the orbit.

255 - 1. The head is tilted. This means the head is moved so that the mandible goes in one lateral direction and the top of the head in the other.
255 - 2. The mandible is tilted to the right or the top of the head is tilted to the left. Same answer.
255 - 3. 15°.
255 - 4. To prevent foreshortening the arch.
255 - 5. Elongation of the arch. Yes. When the patient cannot assume a position with the infraorbitomeatal line parallel with the film.

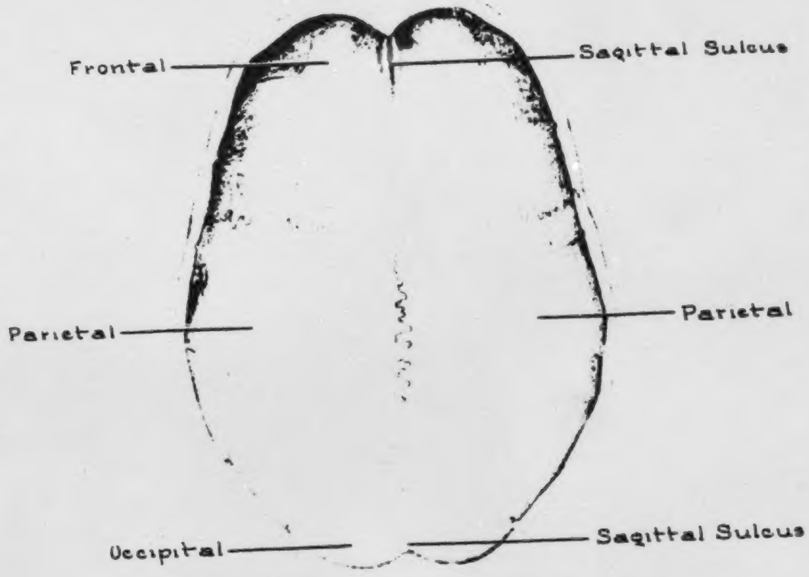
256 - 1. Supine. The patient can maintain the desired position most easily.
256 - 2. The CR is directed along the imaginary line. Both are perpendicular to the film.
256 - 3. The anterior portion of the frontal bone and the anterior edge of upper incisors.
256 - 4. They should be exactly superimposed over each other if the position is correct. If not, one of the structures is anterior or posterior to the other.



Foldout 1. Anatomy of the skull.



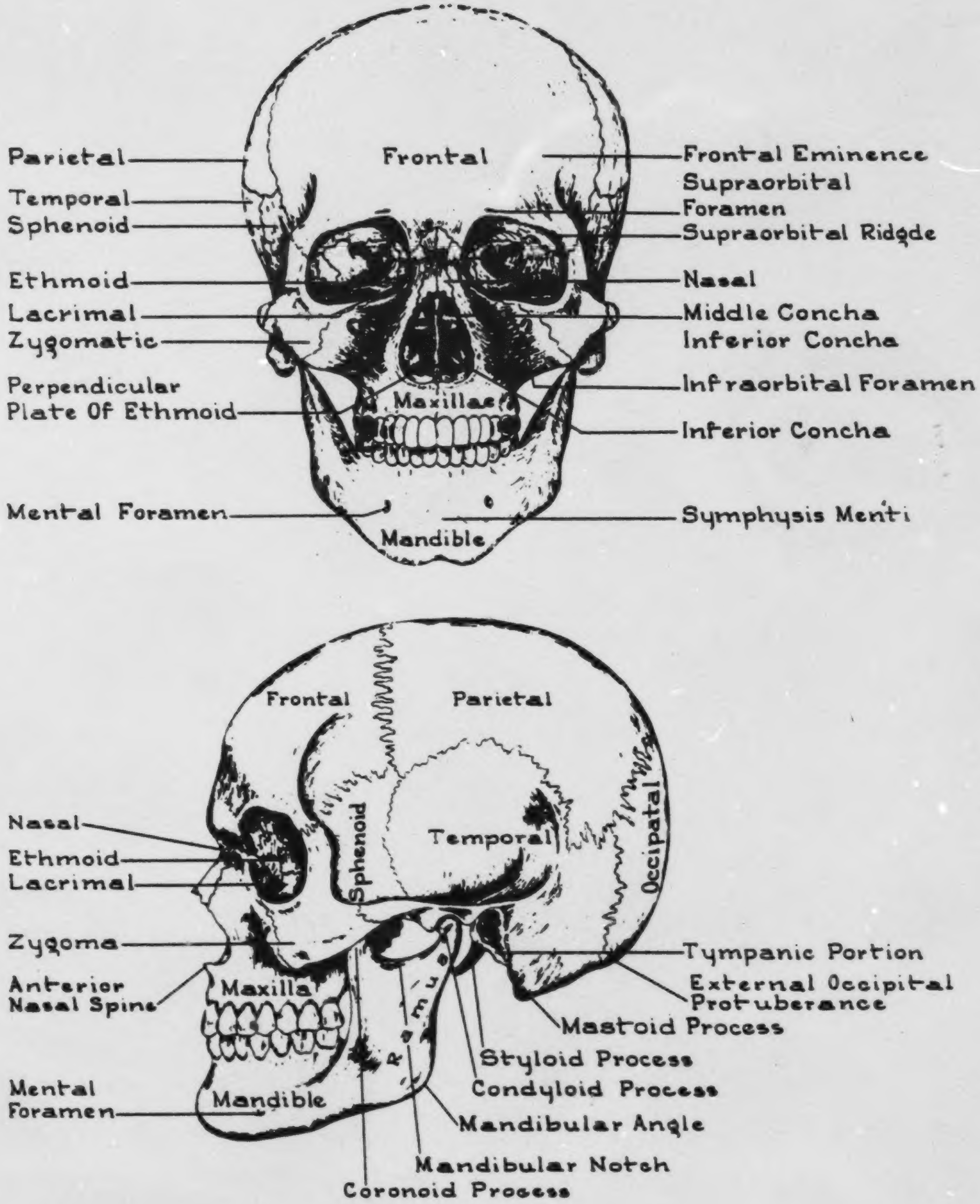
INNER SURFACE OF CRANIAL BASE



INNER SURFACE OF CRANIAL ROOF

Anatomy of the human skull.

Foldout 1. Anatomy of the skull.



Foldout 1. Anatomy of the skull

STOP—

1. **MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.**
2. **USE NUMBER 1 OR NUMBER 2 PENCIL.**

90370 02 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

OSTEOLOGY AND POSITIONING

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

10-5

Multiple Choice

1. (200) Which of the following anatomical reference terms should be used to refer to the anterior surface of the hand?

   a. Palmar or volar.
   b. Dorsal or volar.
   c. Palmar or plantar.
   d. Dorsal or proximal.

2. (201) Select the body plane that divides the body into its associated portions.

   a. Median—left and right; coronal—superior and inferior.
   b. Median—equal halves; coronal—anterior and posterior.
   c. Sagittal—equal halves; transverse—anterior and posterior.
   d. Horizontal—medial and lateral; midsagittal—left and right.

3. (202) Which of the following bones are located in the toes and foot?

   a. Talus, navicular, calcaneus, proximal phalanx, and distal phalanx.
   b. Talus, navicular, triangular, cuboid, coronoid, and first cuneiform.
   c. Cuboid, middle phalanx, calcaneus, navicular, hamate, and distal phalanx.
   d. Cuboid, navicular, first cuneiform, second cuneiform, medial malleolus, and calcaneus.

4. (203) What major bones form the ankle joint?

   a. Lateral malleolus, talus, and fibula.
   b. Medial malleolus, talus, and tibia.
   c. Tibia, fibula, and calcaneus.
   d. Tibia, fibula, and talus.

5. (204) Which of the following structures are located on the proximal portion of the tibia?

   a. Intercondylar eminence, lateral malleolus, and medial and lateral condyles.
   b. Medial malleolus, apex, and bicipital groove.
   c. Intercondylar eminence and tibial tuberosity.
   d. Tibial tuberosity and popliteal region.

6. (205) Where does the patellar ligament attach to the patella?

   a. Apex.
   b. Articular facets.
   c. Posterior condyles.
   d. Inferoposterior surface.

7. (206) Which of the following structures are located on the proximal femur?

   a. Trochanters, fovea capitis, and neck.
   b. Head, trochanters, and intercondyloid eminence.
   c. Popliteal space, trochanters, and fovea capitis.
   d. Condyles, intertrochanteric crest, and intertrochanteric line.

8. (207) Where is the ischial spine located?

   a. Inferior to the obturator foramen.
   b. On the anterior portion of the ischium.
   c. Superior to the posterior inferior iliac spine.
   d. Between the greater and lesser sciatic notches.

9. (207) What structures make up the pubic arch?

   a. Pubic rami.
   b. Pubic tubercles and tuberosities.
   c. Ischial rami and inferior pubic rami.
   d. Symphysis pubis and ischial tuberosities.

19. (214) What parts of the lumbar vertebrae unite to form the apophyseal joints?

    a. Body and disc.
    b. Pedicle and lamina.
    c. Superior and inferior articular processes.
    d. Superior and inferior surfaces of the bodies.

20. (215) With what parts of the thoracic vertebrae do the ribs articulate?

    a. Pedicles and bodies.
    b. Spinous processes and bodies.
    c. Bodies and transverse processes.
    d. Laminae and transverse processes.

21. (216) What two vertebrae form the atlanto-axial articulation?

    a. Atlas and axis.
    b. Axis and third cervical.
    c. Atlas and third cervical.
    d. Seventh cervical and first thoracic.

22. (217) Why are the ribs classified as true, false, and floating?

    a. Some move and some don't.
    b. Some are longer than others.
    c. The posterior articulations are unstable.
    d. Their anterior articulations are different.

23. (218) What are three of the major portions of the sternum?

    a. Clavicular end, manubrium, and body.
    b. Manubrium, body, and xiphoid process.
    c. Manubrium, angle, and xiphoid process.
    d. Gladiolus, angle of Louis, and clavicular notch.

24. (219) Which of the following joints are associated either with the ribs or the body of the sternum?

    a. Xiphisternal and interchondral.
    b. Costochondral and sternomanubrial.
    c. Interchondral and costochondral.
    d. Sternoclavicular and sternomanubrial.

25. (220) Which of the following structures are located on the frontal bone?

    a. Supraorbital foramina and tympanic portions.
    b. Frontal eminences and perpendicular plate.
    c. Zygomatic process and nasal process.
    d. Infraorbital foramina and vomer.

26. (220) What bones make up the roof of the cranium?

    a. Temporals, occipital, and frontal.
    b. Parietals, occipital, and frontal.
    c. Parietals, frontal, and temporals.
    d. Ethmoid, sphenoid, frontal, and occipital.

27. (220) Which of the following structures are part of the temporal bone?

    a. Styloid process, tympanic portion, and coronoid process.
    b. Mastoid process, styloid process, and zygomatic process.
    c. Mandibular fossa, condyloid process, and zygomatic process.
    d. Posterior clinoid processes, mastoid process, and tympanic portion.

10. (208) How many sacral and coccygeal vertebrae are there?

    a. Five sacral and four coccygeal.
    b. Four sacral and four coccygeal.
    c. Five sacral and three coccygeal.
    d. Five sacral and five coccygeal.

11. (209) How many phalanges, metacarpals, and carpals are in the hand and wrist?

    a. Fourteen phalanges, seven metacarpals, and eight carpals.
    b. Fourteen phalanges, five metacarpals, and eight carpals.
    c. Fifteen phalanges, five metacarpals, and seven carpals.
    d. Five phalanges, five metacarpals, and eight carpals.

12. (209) Which of the following tarsal bones are located in the proximal row?

    a. Lunate, triangular, pisiform, and hamate.
    b. Navicular, lunate, capitate, and pisiform.
    c. Navicular, lunate, triangular, and pisiform.
    d. Greater and lesser multangulars, capitate, and hamate.

13. (210) Which of the following bony structures are located on the ulna?

    a. Olecranon process, trochlea, and styloid process.
    b. Radial notch, olecranon process, and coronoid process.
    c. Coronoid process, styloid process, and capitulum.
    d. Radial notch, olecranon process, and radial tuberosity.

14. (211) Which of the following bony structures are located on the distal humerus?

    a. Trochlea, medial epicondyle, semilunar notch, and capitulum.
    b. Epicondyles, olecranon fossa, coronoid fossa, and radial fossa.
    c. Trochlea, lateral epicondyle, coronoid fossa, and radial tuberosity.
    d. Epicondyles, olecranon fossa, olecranon process, and coronoid process.

15. (212) Which one of the following best describes the surgical neck of the humerus?

    a. Rounded eminence on the lateral side.
    b. Deep furrow between the tuberosities.
    c. Constricted portion distal to the tuberosities.
    d. Rounded portion between the tuberosities and the head.

16. (213) What are the names of the two tuberosities of the clavicle?

    a. Manubrial and acromial.
    b. Sternal and manubrial.
    c. Sternal and acromial.
    d. Costal and coracoid.

17. (213) What four bony structures form the two joints of the shoulder?

    a. Glenoid fossa, humerus, acromion process, and clavicle.
    b. Clavicle, humerus, scapular fossa, and acromion process.
    c. Glenoid fossa, acromion process, manubrium, and humerus.
    d. Humerus, scapular spine, coracoid process, and acromion process.

18. (214) Which of the following best describes the location of the lamina of a lumbar vertebra?

    a. Superior to the pedicle.
    b. Between the transverse processes.
    c. Between the body and the transverse process.
    d. Between the spinous and transverse processes.

28. (220) Where is the pituitary gland located?

- a. On the sella turcica.
- b. On the tympanic portion.
- c. Superior to the crista galli.
- d. Behind the posterior clinoid processes.

29. (220) Which of the following descriptions best identifies the location of the crista galli?

- a. In the roof of the nasal cavity.
- b. Extends upward from the cribriform plate.
- c. Posterior to the anterior clinoid processes.
- d. Extends downward from the perpendicular plate.

30. (221) The coronal suture is located between the

- a. occipital and parietals.
- b. parietals and sphenoid.
- c. temporal and sphenoid.
- d. frontal and parietals.

31. (222) What two fontanelles, when ossified, become the bregma and lambda?

- a. Both anterolaterals.
- b. Both posterolaterals.
- c. Anterior and posterior.
- d. Anterior and right posterolateral.

32. (223) Which of the following structures are located on the maxilla?

- a. Inferior turbinate, anterior nasal spine, and zygomatic arch.
- b. Infraorbital foramen, anterior nasal spine, and temporal process.
- c. Infraorbital foramen, zygomatic process, and palatine process.
- d. Anterior nasal spine, orbital process, and perpendicular plate.

33. (223) With what bones do the nasal bones articulate?

- a. Frontal and maxillae.
- b. Frontal and zygomatic.
- c. Maxillae and zygomatic.
- d. Zygomatic and lacrimal.

34. (223) Where are the inferior nasal conchae located?

- a. Below the vomer.
- b. Posterior to the nasal bones.
- c. Along the medial walls of the orbits.
- d. Along the lateral walls of the nasal cavity.

35. (223) What three structures are located on the superior portion of the mandible?

- a. Coronoid process, mandibular notch, and ramus.
- b. Condyloid process, coronoid process, and ramus.
- c. Condyloid process, coronoid process, and mandibular notch.
- d. Condyloid process, intercondylar notch, and mandibular angle.

36. (224) What sinuses have the alveolar processes as their floor?

- a. Frontal.
- b. Maxillary.
- c. Ethmoidal.
- d. Sphenoidal.

37. (225) At what angle and for what reason should the central ray be directed for an AP projection of the metatarsals?

    a. 15° cephalic for a fracture and vertical for a foreign body.
    b. Vertical because the metatarsals are parallel with the film.
    c. 15° cephalic because the metatarsals form the same angle with the film.
    d. Either 15° cephalic or vertical depending upon the portion of the metatarsals requiring visualization.

38. (225) What tarsal bones are not adequately demonstrated on an AP projection of the foot?

    a. Calcaneus only.
    b. Talus and calcaneus.
    c. Talus and navicular.
    d. Third cuneiform and calcaneus.

39. (226) An inferosuperior projection of the calcaneus is made with the plantar surface of the foot perpendicular to the film and the CR angled 40° cephalic. How much of the calcaneus would be deomonstrated?

    a. Approximately the posterior half.
    b. To the posterior margin of the talocalcaneal joint.
    c. The entire calcaneus except for the most superior portion.
    d. To the level of the trochlear process and sustentaculum tali.

40. (226) Why is it important to properly position the calcaneus and use the correct CR angulation for the inferosuperior projection?

    a. It prevents foreshortening.
    b. It increases the magnification.
    c. Injuries to the heel are usually serious.
    d. Fractures of the calcaneus are particularly difficult to demonstrate.

41. (227) Why should a medial oblique projection be included during an examination of the ankle?

    a. It demonstrates the talocalcaneal joint.
    b. It provides clear demonstration of the lateral malleolus.
    c. It provides clear demonstration of the medial malleolus.
    d. Most fractures of the ankle are demonstrated only by the oblique projection.

42. (227) What projections should be performed for a stress examination of the ankle joint?

    a. AP with forced inversion and AP with forced eversion only.
    b. Standard AP, lateral, and oblique plus AP with forced eversion.
    c. Standard AP, lateral, and oblique plus AP with forced inversion.
    d. Standard AP, AP with forced inversion, and AP with forced eversion.

43. (228) A tunnel projection of the knee is taken to demonstrate which of the following bony structures?

    a. Intercondylar eminence and intercondyloid fossa.
    b. Intercondylar eminence and patella.
    c. Intercondyloid fossa and patella.
    d. Femoral condyles and epicondyles.

44. (228) How should the leg and femur be positioned with respect to the X-ray table for Homblad's projection of the knee?

    a. Leg and femur parallel.
    b. Leg—parallel; femur—forms a 20° angle.
    c. Leg—parallel; femur—forms a 70° angle.
    d. Leg—slightly elevated; femur—forms a 20° angle.

45. (229) Which of the following instructions should be used to locate the head of the femur?

    a. Select a point where a transverse plane through the symphysis pubis intersects a sagittal plane 2 inches medial to the ASIS intersect.
    b. Select a point where a transverse plane through the most superior point of the greater trochanter intersects a sagittal plane 2 inches medial to the ASIS.
    c. Imagine a line connecting the ASIS to the symphysis pubis; imagine another line which is perpendicular to and bisects the first line. Select a point 3 inches along the second line.
    d. Imagine a line connecting the symphysis pubis to the greater trochanter; imagine another line which bisects the first line. Select a point 2 inches along the second line.

46. (230) An imaginary line connects the ASIS and symphysis pubis. Another imaginary line is perpendicular to and bisects the first line. The second line

    a. passes through the greater trochanter.
    b. is parallel to the long axis of the femoral shaft.
    c. is used as a reference for film placement during a lateral hip projection.
    d. is parallel with the CR for an axial projection of the intertrochanteric crest.

47. (231) Why should the third finger be positioned parallel with the film for an oblique projection?

    a. It superimposes the articular surfaces.
    b. It demonstrates the interphalangeal joint spaces.
    c. It projects the nutrient artery canal in profile.
    d. A hairline fracture of the middle phalanx is easier to demonstrate.

48. (232) Why should the hand be rotated slightly toward the radial side for a Gaynor-Hart projection of the carpal canal?

    a. It elongates the greater multangular.
    b. The radial styloid process is better visualized.
    c. It projects the hamulus process and pisiform free from superimposition.
    d. The canal is slightly rotated with respect to the palmar surface of the hand.

49. (233) If a lateral projection of the elbow is made with the hand pronated, how will the radiograph be affected?

    a. The coronoid process will be superimposed over the radial tuberosity.
    b. The head of the radius will not be in the lateral position.
    c. The semilunar notch will not be visualized.
    d. The olecranon process will appear unclear.

50. (233) A medial oblique projection of the elbow is made to demonstrate the coronoid process. The radiograph shows the coronoid process superimposed over the radial head. How can the superimposition be eliminated on a subsequent oblique projection?

    a. Rotate the elbow 10° more than the original rotation.
    b. Use a 25° lateral oblique position.
    c. Rotate the elbow 40° to 45°.
    d. Flex the elbow slightly.

51. (233) Instead of an AP projection, which of the following radiographs should be made of an elbow which is hyperflexed because of injury or treatment?

a.	Extension AP.	c.	Lateral oblique.
b.	Medial oblique.	d.	Jones' projection.

52. (234) Which of the following structures are visualized better on the external than on the neutral or internal rotation radiograph of the shoulder?

a. Humeral head and lesser tuberosity.
b. Humeral head and greater tuberosity.
c. Bicipital groove and lesser tuberosity.
d. Bicipital groove and greater tuberosity.

53. (235) An AP (open-mouth odontoid) radiograph of the atlas and axis shows the upper incisors projected below the level of the base of the skull and superimposed over the atlas. What action should be taken to correct the patient's position on a subsequent radiograph?

a. Flex the head 10° if possible—if not, angle the CR 10° caudally.
b. Extend the head 10° if possible—if not, angle the CR 10° cephalically.
c. Flex the head—the amount depending upon the distance between the lower edge of the upper incisors and the base of the skull.
d. Extend the head—the amount depending upon the distance between the lower edge of the upper incisors and the base of the skull.

54. (236) How many degrees should the patient be rotated and how should the CR be directed to perform oblique projections of the cervical spine?

a. Body rotation—45°; CR—15° to 20° cephalic for posterior obliques and caudad for anterior obliques.
b. Body rotation—45°; CR—15° to 20° cephalic for anterior obliques and caudad for posterior obliques.
c. Body rotation—90°; CR—20° cephalic.
d. Body rotation—90°; CR—20° caudad.

55. (237) When performing oblique projections of the cervical spine on a supine patient suspected of having a fracture, what CR angulation should you use?

a. 90° lateral and 30° caudad.
b. 45° medial and 15° to 20° caudad.
c. 45° medial and 15° to 20° cephalic.
d. 90° lateral and 30° to 40° cephalic.

56. (238) An initial oblique radiograph of the lumbar spine shows the medial portions of the transverse processes projected over the anterior portions of the vertebral bodies. Most likely, visualization of the pars interarticularis is

a. poor because the patient is rotated less than 45°.
b. poor because the patient is rotated more than 45°.
c. good because the patient is rotated the appropriate amount.
d. good because visualization of the pars interarticularis is not affected by patient rotation.

57. (239) Best results are obtained if a lateral projection of the lumbar spine is made employing which of the follwoing factors?

a. An angled CR and an elevated pelvis.
b. An angled CR and a small amount of lumbar "sag."
c. A perpendicular CR and the intervertebral spaces parallel with the film.
d. A perpendicular CR and the long axis of the spine parallel with the film.

58. (239) If an angled CR is used for the lateral projection of the lumbar spine, the direction and the average amount of the angulation is

a. caudad—8° for males and 5° for females.
b. caudad—5° for males and 8° for females.
c. cephalic—10° for males and 5° for females.
d. cephalic—5° for males and 10° for females.

59. (240) Which one of the following positions demonstrates the right apophyseal joints of the thoracic spine?

a. From the right lateral recumbent position the patient's left side is rotated anteriorly 20°.
b. From the left lateral recumbent position the patient's right side is rotated anteriorly 20°.
c. From the supine position the patient's right side is rotated upward 45°.
d. From the supine position the patient's left side is rotated upward 45°.

60. (241) When performing radiographs of the ribs, the breathing technique is used to

a. reduce part motion.
b. increase visualization.
c. eliminate the heart shadow.
d. compensate for the superimposition of the diaphragm.

61. (241) Which of the following ribs of a short, heavy patient should be radiographed below the diaphragm on expiration?

a. Posterior ribs ten through twelve; axillary ribs six and seven.
b. Posterior ribs six and seven; anterior ribs five and six.
c. Posterior ribs eight through ten; axillary ribs eight and nine.
d. Posterior ribs eleven and twelve; anterior ribs five and six.

62. (242) When checking the spinous processes for rotation of a PA chest, why should several continuous vertebrae be evaluated?

a. Thoracic vertebrae are atypical.
b. Deviation of a single spinous process indicates the CR is not horizontal.
c. The spinous process of the third thoracic vertebra is usually deviated.
d. It is common for one spinous process to be deviated in a properly positioned chest.

63. (242) A PA chest radiograph shows slight rotation with the left side of the chest away from the film. How would the following structures most likely appear?

a. Heart—shifted to the left; right sternoclavicular joint—superimposed over the spine.
b. Heart—shifted to the right; left sternoclavicular joint—superimposed over the spine.
c. Heart—shifted to the left; left sternoclavicular joint—superimposed over the spine.
d. Heart—shifted to the right; right sternoclavicular joint—superimposed over the spine.

64. (242) A full inspiratory PA chest is normally the visualization of how many ribs?

a. Eight posterior or eight anterior.
b. Nine posterior or nine anterior.
c. Ten posterior or seven anterior.
d. Nine posterior or six anterior.

65. (243) If a lateral radiograph of the skull shows slight anterior rotation, which one of the following descriptions best relates the position of the median plane of the head when the radiograph was made?

a. It was parallel with the film.
b. The anterior portion was nearer the table.
c. If extended, it intersected with the table above the head.
d. If extended, it intersected with the table behind the head.

66. (243) To what point should the CR be directed for a lateral skull if the examination is being performed as part of a workup for headaches?

a. Three-fourths of an inch anterosuperiorly to the external auditory meatus.
b. One and one-half inches posterosuperiorly to the external auditory meatus.
c. To the external auditory meatus.
d. To the center of the skull.

67. (244) If the dense lines made by the orbital plates of the frontal bone and the lesser wings of the sphenoid appear separated on a lateral radiograph of the skull, what skull position(s) is indicated?

a. True lateral.
b. Anterior angulation.
c. Anterior or posterior rotation.
d. Superior or inferior longitudinal angulation.

68. (245) Where are the petrous ridges projected on Caldwell's radiograph of the skull?

a. Over the maxillary sinuses.
b. In the middle of the orbits.
c. Slightly superior to the supraorbital ridges.
d. To the level of the lower margins of the orbits.

69. (245) A straight PA projection of the skull, rather than a Caldwell projection, should be performed when the

a. greater wings of the sphenoid are under study.
b. patient cannot tolerate the supine position.
c. frontal bone is specifically to be demonstrated.
d. examination is performed under portable conditions.

70. (246) If an AP projection of the skull is being made, what CR angulation and direction should be used to demonstrate the entire foramen magnum?

a. 50° to 60° caudad.
b. 30° to 35° caudad.
c. 30° cephalic.
d. 15° cephalic.

71. (247) How should the orbitomeatal line be positioned for Waters' projection of the skull?

a. Perpendicular to the film.
b. So that it forms a 37° angle with the table.
c. So that it forms a 23° angle with the table.
d. Parallel with the transverse axis of the film.

72. (248) Best results are obtained with a submentovertical projection if the

a. orbitomeatal line is parallel with, and the CR is perpendicular to, the film.
b. head is tilted 15° toward the side under study, and the CR is angled laterally 5°.
c. infraorbitomeatal line is parallel with, and the CR is perpendicular to, the film.
d. median plane is perpendicular to the film, and the CR is perpendicular to the infraorbitomeatal line.

73. (249) The ears should be taped forward for certain projections of the mastoids because

a. the positioning is more difficult.
b. extraneous shadows reduce detail.
c. less secondary radiation is produced.
d. it is more comfortable for the patient.

74. (250) What CR angulation(s) and direction(s) should be used for Law's projection, tube-tilt method?

a. 23° cephalic.
b. 30° to 35° caudad.
c. 15° toward the face and 15° caudad.
d. 15° toward the occiput and 15° caudad.

75. (251) When a Stenver's projection is being performed, if the patient has a brachycephalic skull, in what direction and how many degrees should the head be rotated to demonstrate the right petrous ridge?

a. The face is rotated to the left 35°.
b. The face is rotated to the left 45°.
c. The posterior portion of the skull is rotated to the left 45°.
d. The posterior portion of the skull is rotated to the right 54°.

76. (252) If Mayer's projection is being performed, what CR angulation and direction and what part rotation and direction should be used?

a. CR—25° caudad; face rotated 30° toward side under study.
b. CR—10° caudad; face rotated 30° away from side under study.
c. CR—45° caudad; face rotated 45° toward side under study.
d. CR—12° cephalic; face rotated 45° away from side under study.

77. (253) If the Rhese's projection of the right optic foramen is being performed, in what direction and how many degrees should the head be rotated from the PA position?

a. Rotate the face to the left 45°.
b. Rotate the face to the right 53°.
c. Rotate the posterior portion of the head to the left 37°.
d. Rotate the posterior portion of the head to the right 37°.

78. (254) If the head is properly positioned for the Rhese's projection of the optic foramen, where should the structure appear on the radiograph?

a. In the middle of the lower, outer quadrant of the orbit.
b. In the upper, outer quadrant of the orbit.
c. Just inferior to the petrous ridge.
d. In the center of the orbit.

79. (255) If the basic submentovertical projection is used to demonstrate only the left zygomatic arch, what procedure should be used to project the structure away from the side of the head?

a. Direct the CR perpendicularly to the orbitomeatal line.
b. Tilt the top of the head to the right 15°.
c. Tilt the top of the head to the left 15°.
d. Direct the CR 20° medially.

80. (256) If a superoinferior projection of the nasal bones is being performed, what structures should be positioned in the same plane to allow maximum visualization of them?

a. The glabella and acanthion.
b. The supraorbital ridge and acanthion.
c. The glabella and anterior portion of the upper incisors.
d. The anterior border of the nasal bones and the anterior portion of the upper incisors.

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CDC 90370

RADIOLOGY TECHNICIAN

(AFSC 90370)

Volume 3

Special Techniques

Extension Course Institute

Air University

10-5

Preface

THIS VOLUME of your CDC training is devoted to 8 chapters consisting of 10 types of radiographic examinations we have called special techniques. As we mention throughout the volume, the exact procedures used depend mostly upon the preference of your radiologist, although some other factors also influence the procedures used.

You may not be performing some of these examinations in your radiology department at present. Also, you may not have performed any of them in the past. These circumstances should not lessen your desire to learn, however, because at one time or another during your Air Force career you will be required to perform and supervise the performance of these special techniques.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to School of Health Care Sciences/MST, Sheppard AFB TX 76311. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 27 hours (9 points).

Material in this volume is technically accurate, adequate, and current as of December 1974.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Mammography

INTRAMAMMARY masses, such as carcinoma, were once detectable only by palpation, and identifiable only via biopsy. In many cases, by the time they were detected, the masses were so large that radical mastectomy was the only course of therapeutic action, and metastasis had already occurred. Today with proper mammographic techniques, some of these masses can be radiographically demonstrated in an early stage. Consequently, at times, treatment can be initiated at a time when it will do the most good.

As is the case with most radiographic examinations, an understanding of the anatomy involved is necessary in order to produce good mammograms. Therefore, we begin our discussion with a review of the anatomy of the breast. Following that, we will discuss some of the technical aspects of producing good mammograms.

1-1. Anatomical Considerations of the Breast

Functionally, the female breasts are accessory glands of the reproductive system. From a structural point of view, they are made up of various types of tissue in varying amounts depending upon the age and obstetrical condition of the patient.

400. Given a list of selected anatomical parts of a breast, match each with an appropriate descriptive statement or phrase in another list.

External Structure of the Breast. The surface landmarks of the breast include the nipple and the areola (see fig. 1-1). The nipple is perforated by 15- to 20-minute ducts. The areola is the highly pigmented area surrounding the nipple.

Internal Structure of the Breast. Our discussion of the internal structure of the breast is mainly concerned with the three types of breast tissue and the retromammary space. See figure 1-2.

Fibrous tissue. Fibrous breast tissue consists of two layers of fascia, suspensory ligaments, and an irregularly pitted framework for the glandular tissue. The fascia layers, superficial and deep, are joined and completely house the mammary gland. The suspensory ligaments are vertical bands of elastic fibrous tissue and connect the deep layer of fascia with the skin. The remainder of the fibrous

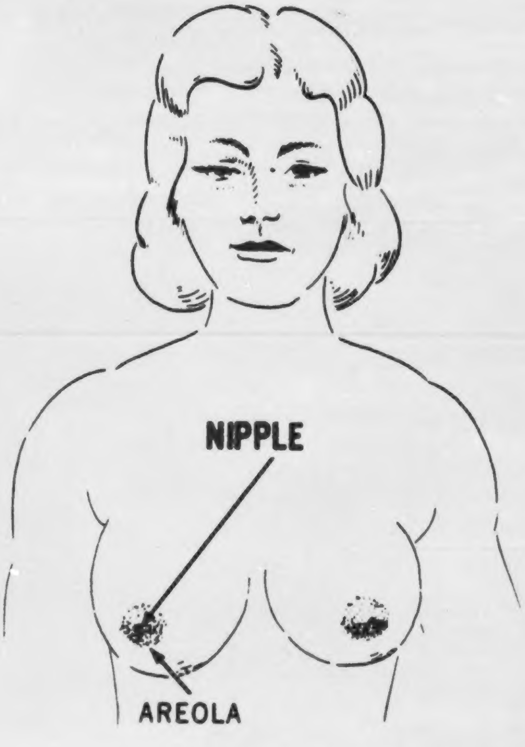

Figure 1-1. Breast showing the nipple and areola.

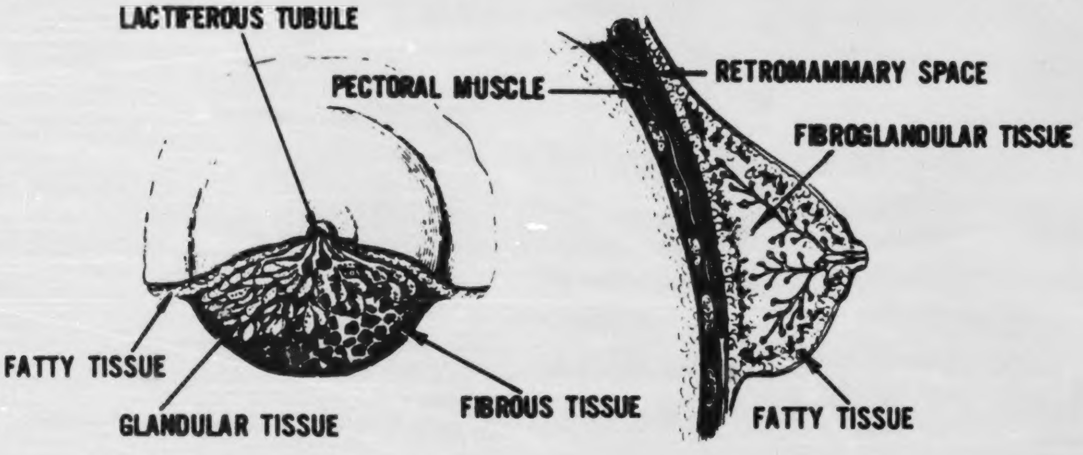

Figure 1-2. Internal structure of the breast.

tissue comprises the honeycombed framework for the mammary gland.

Glandular tissue. The glandular tissue (mammary gland) consists of 15 to 20 lobes, each of which is composed of numerous lobules. All are interconnected by the lactiferous ducts, which form a distinct network. The tiny ducts from the lobules, called terminal ducts or acini, empty into the larger main ducts. These in turn empty into the lactiferous tubules that extend from each lobe into the nipple.

Fatty tissue. Fatty (adipose) tissue completely surrounds, and is distributed in, the glandular tissue in varying amounts depending upon the patient's age and obstetrical condition.

Retromammary space. Between the posterior portion of the mammary gland and the pectoral muscle is the retromammary space. This space is radiographically significant, as we shall see later in this chapter.

Exercises (400):

Match the breast structure in column B with the appropriate statement or phrase in column A by placing the letter of the column B structure in the space provided in column A. Each column B item may be used once, more than once, or not at all. In addition, more than one column B item may match a single column A entry.

Column A

____ 1. External landmarks.
____ 2. Composed of numerous lobules.
____ 3. Fascia.
____ 4. Surrounds and is distributed in mammary gland.
____ 5. Extend from glandular lobes to nipple.
____ 6. Between mammary gland and chest wall.
____ 7. Suspensory ligaments.

Column B

a. Nipple.
b. Fatty tissue.
c. Glandular tissue.
d. Areola.
e. Fibrous tissue.
f. Terminal ducts.
g. Lactiferous tubules.
h. Retromammary space.
i. Lactiferous ducts.

401. Specify the relative densities of the three types of breast tissue, and name the type requiring the least exposure and the type requiring the most exposure, assuming all other factors are equal.

Structural Variations of the Breast. The density of the breast and, consequently, the exposure required depends in part upon the ratio of fibroglandular (fibrous and glandular) tissue to fatty tissue. Fibrous tissue and glandular tissue are approximately equal in densities while fatty tissue is the least dense of the three types of breast tissue. The more fibroglandular tissue there is in the breast, in relation to the amount of fatty tissue, the greater the density of the breast.

The breasts usually undergo a gradual change in tissue ratio from the adolescent years to the postmenopausal years. This gradual change is the basis for categorizing the breasts into one of the five following types. See figure 1-3.

Adolescent breast. The adolescent (virginal) breast has a rudimentary ductal system and consists mainly of fibroglandular tissue.

Mature breast. In the mature breast, there is an increasing amount of adipose tissue and a corresponding decrease in fibroglandular tissue.

Lactating breast. During pregnancy, hormonal stimulation causes an increase in the size of the breast. Glandular tissue grows and replaces much of the fat. As a result, the lactating, or milk-producing, stage compares with the adolescent breast in terms of density.

Menopausal breast. As a woman approaches and passes through menopause, there is a further increase in adipose tissue, with little fibroglandular tissue present.

Atrophic breast. At this stage, adipose tissue has completely replaced the fibroglandular tissue. The atrophic breast is less dense than any of the others.

Exercises (401):

1. What are the relative densities of the three types of breast tissue?

2. Assuming all other factors are equal, what type of breast requires the least exposure and why?

3. Assuming all other factors are equal, what type(s) of breast require(s) the most exposure?

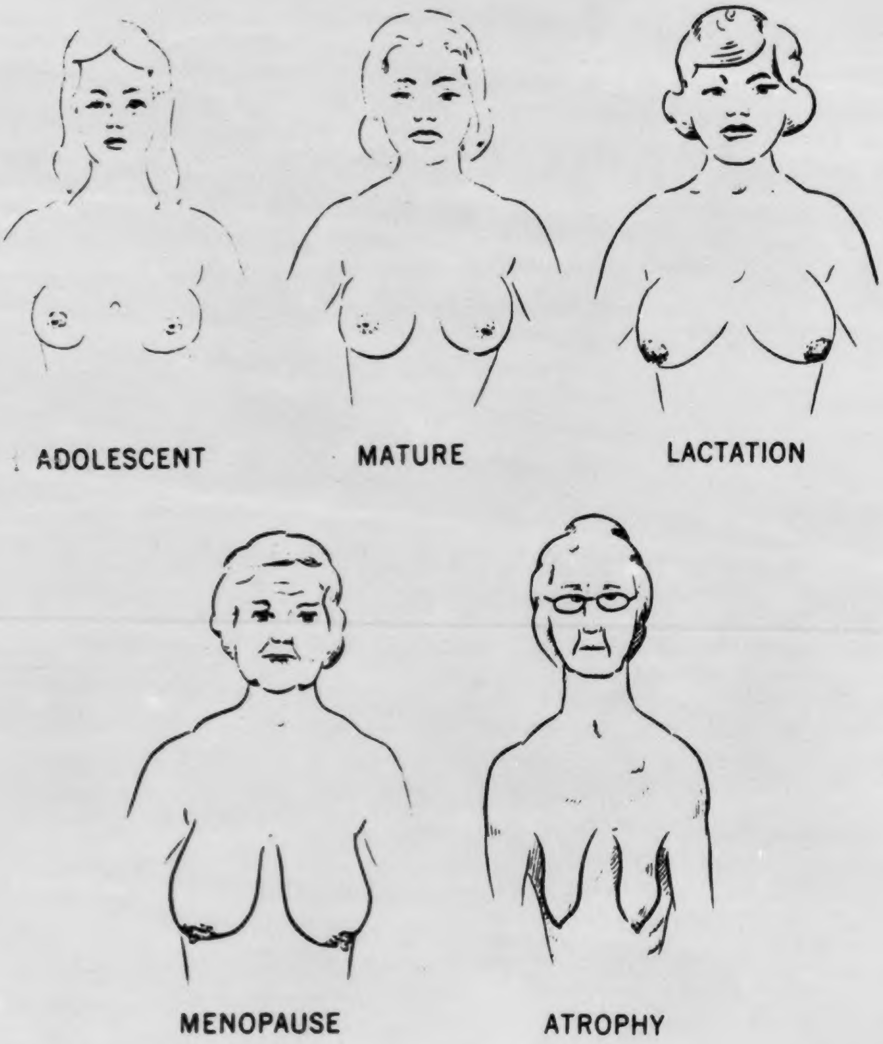

Figure 1-3. Structural variations of the breast.

1-2. Technical Considerations of Mammography

In this section, we will discuss the various technical aspects of producing good mammograms. Areas covered include tube requirements, films and screens, and exposure factors.

402. Given a list of statements concerning the X-ray tube requirements during mammography, indicate which are true and which are false.

Tube Requirements. Several factors such as focal spot size, tube capacity, filtration, and beam restrictors must be given special consideration in order to produce good mammograms.

Focal spot size. One indication of pathology on a mammogram is a cluster of minute calcifications. These calcifications are so small at times that they cannot be seen without a magnifying glass. Since the size of the focal spot is one of the major factors affecting the detail on a radiograph, it follows that mammograms should be made with the smallest focal spot in your department that will withstand the heat generated by the exposures.

Tube capacity. The heat generated by mammographic exposures may be relatively high because high mAs (milliampere seconds) and low kVp (kilovolts peak) are sometimes used. This combination of exposure factors generates a tremendous amount of H.U. (heat units). An example of an exposure is 26 kVp and 1,800 mAs, which amounts to 46,800 H.U. Since three projections of each breast may be made during an examination, the total number of H.U. is 280,800. The anode storage capacity of some X-ray tubes is considerably less than 280,800 H.U. Therefore, it may be necessary to allow some cooling time between exposures to prevent damage to the X-ray tube. Of course, the exposure factors must also be checked against the single exposure rating chart to prevent tube damage.

Filtration. Demonstration of the differences between breast tissue requires a soft, heterogeneous X-ray beam. Ideally, then, mammography should be accomplished using no filtration. However, as previously discussed in Volume 1, in order to keep patient exposure to a minimum, you are required to use a minimum amount of filtration depending upon the kVp used. We bring the subject up again at this point to stress to you that you should not exceed the minimum filtration requirements during mammograms. This means that if the inherent filtration of your tube is 0.5 millimeters (mm) of aluminum, you should remove all of the added filtration. Keep in mind that an ordinary collimator usually contains a certain amount of aluminum equivalent filtration and, therefore, must be removed. Special collimators are available with minimum filtration and can be used.

Beam restrictors. The X-ray field for a mammogram should be restricted so that it covers the breast plus a 1-inch border. This tightly restricted X-ray field is necessary because scatter radiation can cause film fogging and lower the contrast. Since adequate contrast on a mammogram is somewhat difficult to obtain, film fogging must be kept to an absolute minimum.

The particular beam restrictor used for a mammogram should be designed to reduce the off-focus radiation reaching the film. Off-focus radiation is that radiation emitted from areas of the anode other than the target. Off-focus radiation reaching the film reduces image detail because, in actuality, it causes an increase in the effective focal spot size. Notice in figure 1-4 that the aperture of the cylinder in drawing A is different from that in drawing B. Also, notice that the aperture in drawing B absorbs some off-focus radiation which would reach the film in drawing A. Specially constructed cylinders are made with small, conical-shaped apertures like the one shown in figure 1-4, A, to reduce off-focus radiation.

Exercises (402):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. Mammograms should demonstrate minute objects invisible to the naked eye.
T F 2. You should use the smallest focal spot in your department to perform mammography.
T F 3. The generation of H.U. during a mammogram is especially significant because of the exposure factors.
T F 4. Anode storage capacity is the only tube rating consideration necessary for mammography.
T F 5. The X-ray field for a mammogram should cover the breast plus a 1-inch border.
T F 6. Reduction of the contrast on a mammogram can result from improper beam restriction.
T F 7. Off-focus radiation can reduce image detail on a mammogram.
T F 8. A beam restrictor designed to reduce off-focus radiation has a large aperture.
T F 9. Absorption of off-focus radiation by a cylinder aperture can reduce the effective focal spot size.

403. Cite specified details significant to the use of films and intensifying screens in mammography.

Films and Screens. Standard coarse-grained

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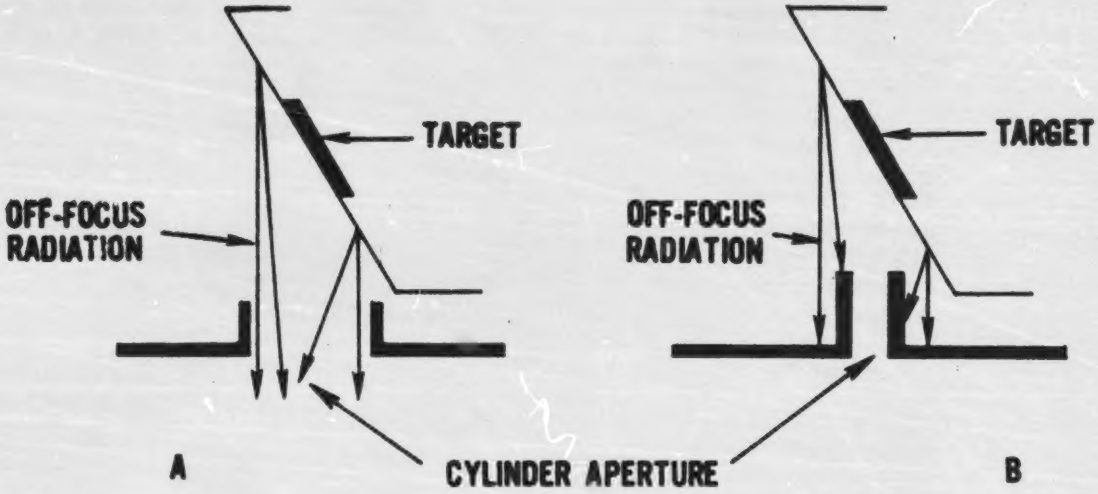

Figure 1-4. Comparison between the absorption of off-focus radiation with different cylinder apertures.

films are not suitable for mammography because the detail produced on the radiographs is inadequate. Fine-grained industrial or special mammographic films must be used. Such films are available from several manufacturers.

The films are also available with different speeds. The fact that films with different speeds are available commerically in a single package allows you to produce radiographs of different densities from a single exposure. Some radiologists prefer multifilm exposures because they permit good visualization of both thick and thin portions of the breast from a single exposure. You can easily assemble films of various speeds in a direct exposure film holder to serve the same purpose.

Some industrial or mammographic films can be processed in automatic processors while others must be hand-processed. In either case, be sure to follow the film manufacturer's processing instructions.

While intensifying screens have not been used extensively in the past for mammography, they are now preferred by some radiologists. The problem with using screens is the normal loss of detail that results. However, special high-detail screens made for mammography which result in less detail loss are now available and are recommended for use. The big advantage of using screens is that mammographic exposure times, up to 6 seconds, can be reduced, thus helping to eliminate part motion.

Exercises (403):

1. Why shouldn't you use standard radiographic films for mammography?

2. What is the difference in the grain between standard and industrial or mammographic films?

3. Give two ways of obtaining radiographs with various densities from a single exposure.

4. What is the advantage of obtaining films with different densities from a single exposure?

5. State a good rule to follow when processing mammograms.

6. If intensifying screens are used for mammography, what type of screens should be used?

7. Give one disadvantage and one advantage when using intensifying screens for mammography.

404. Specify the kVp that should be used for the craniocaudal and lateral projections of the breasts and for the axillary projection of the breast, and state why they should be used.

Exposure Factors. The mAs and focal film distance (FFD) used for mammograms are somewhat flexible as we shall point out later in this section. One factor, however, must be used within certain limits. That factor is kVp, which is the first topic of our discussion of exposure factors.

kVp. When you perform a radiograph of a bony structure—the leg, for example—there is no difficulty providing adequate contrast between the bones and muscle. You will recall we discussed the reason for this in Volume 1. We said that because of the significant difference between the atomic numbers of bone and muscle, the selective absorption of X-ray photons is sufficiently different to result in two distinct densities on the radiograph—or, we may say, adequate contrast.

In the breast, we are primarily concerned with three types of tissue. Two of them we discussed at the beginning of this chapter—fibroglandular and fatty. The third type is the pathological tissue we are trying to demonstrate on the radiograph. Providing adequate contrast between these three types of tissue is much more difficult than doing so between bone and muscle because the absorption properties of fibroglandular, fatty, and pathological tissue are *nearly* equal. We emphasized "nearly" because there is some difference—and the difference can be recorded. To demonstrate the difference between the tissues, you must use low kVp. By low kVp we mean between 20 to 30 for most craniocaudal and lateral projections. The axillary projection sometimes requires up to 50 kVp because a certain amount of muscle tissue must be penetrated.

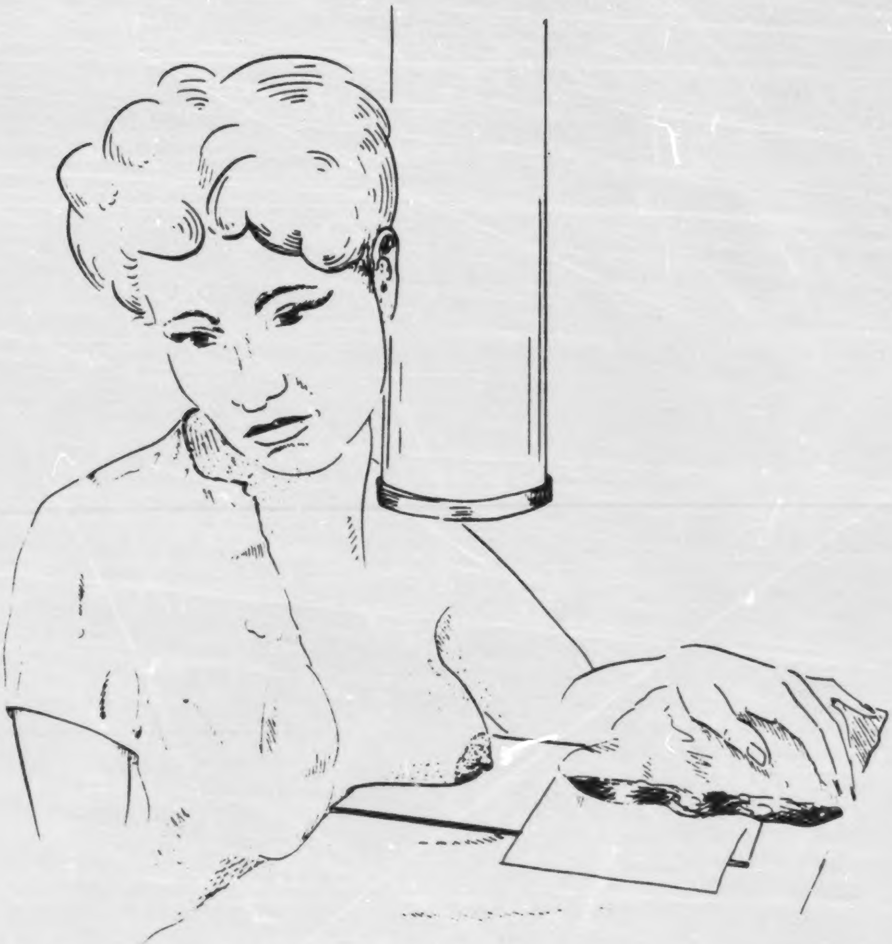

Figure 1-5. Craniocaudal projection of the breast.

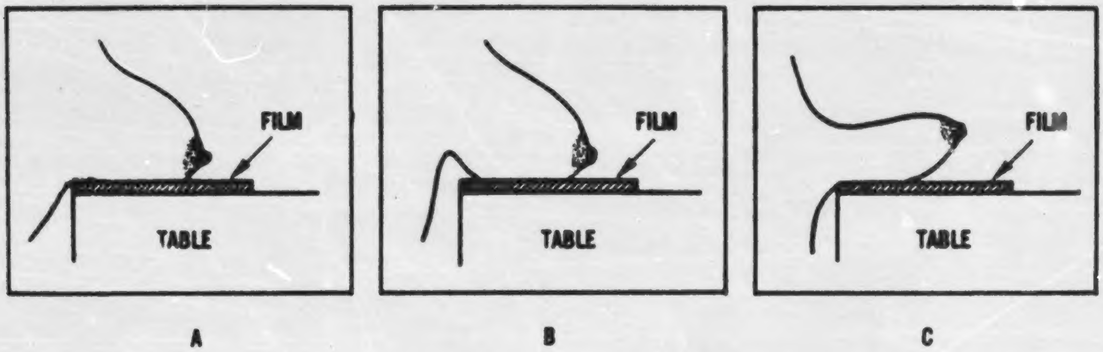

Figure 1-6 Relationships between breast, film, and X-ray table.

Exercises (404):

1. What kVp should be used for the craniocaudal and lateral projections of the breasts? Why?

2. What kVp should be used for the axillary projection of the breast? Why?

405. Cite key features relating to the selection of mAs and FFD for mammographic examinations.

mAs and Focal Film Distance. The specific mAs and FFD you use depend upon several factors. The mAs and FFD are also closely related to each other since they both affect the quantity of radiation reaching the film.

One factor that obviously affects the mAs needed is the speed of the film. Some slow fine-grained films require up to 1,800 mAs for the proper amount of blackening, while others do not need as much. The use of intensifying screens obviously reduces the mAs required.

When establishing the mAs, you must also consider the individual mA and time values. Exposure time should be kept as short as possible since part motion is the most common cause of detail loss on mammograms. A long exposure used with a small mA station increases the possibility of repeat examinations due to part motion. If the small focal spot on your unit requires a long exposure to fulfill the mAs requirement, it is probably better to use a larger focal spot and sacrifice some detail than to *continuously* repeat examinations because of part motion.

If you must use a large focal spot, the loss of detail can be partially offset by using a relatively long FFD. By a long FFD, in this case we mean up to 40 inches. The FFD range for mammograms is normally 20 to 40 inches. The specific distance you use depends in part on your radiologist's preference. Some radiologists prefer to use nearly 40 inches for all mammograms because this reduces the skin dose to the patient; however, the long FFD requires more exposure due to the inverse square law. While a short FFD can reduce the exposure, it results in a loss of detail due to increased magnification. Naturally, a short FFD increases the skin dose to the patient.

Exercises (405):

1. Name three factors affecting the mAs needed for a mammographic examination.

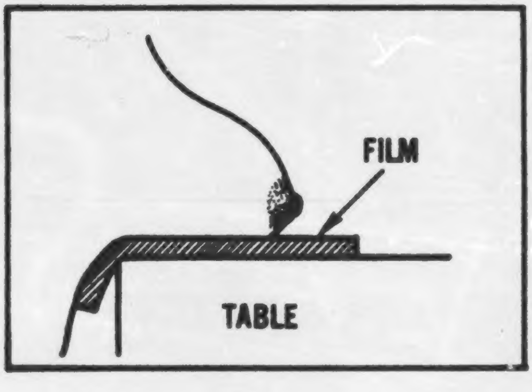

Figure 1-7. Craniocaudal projection showing film curved against the chest wall.

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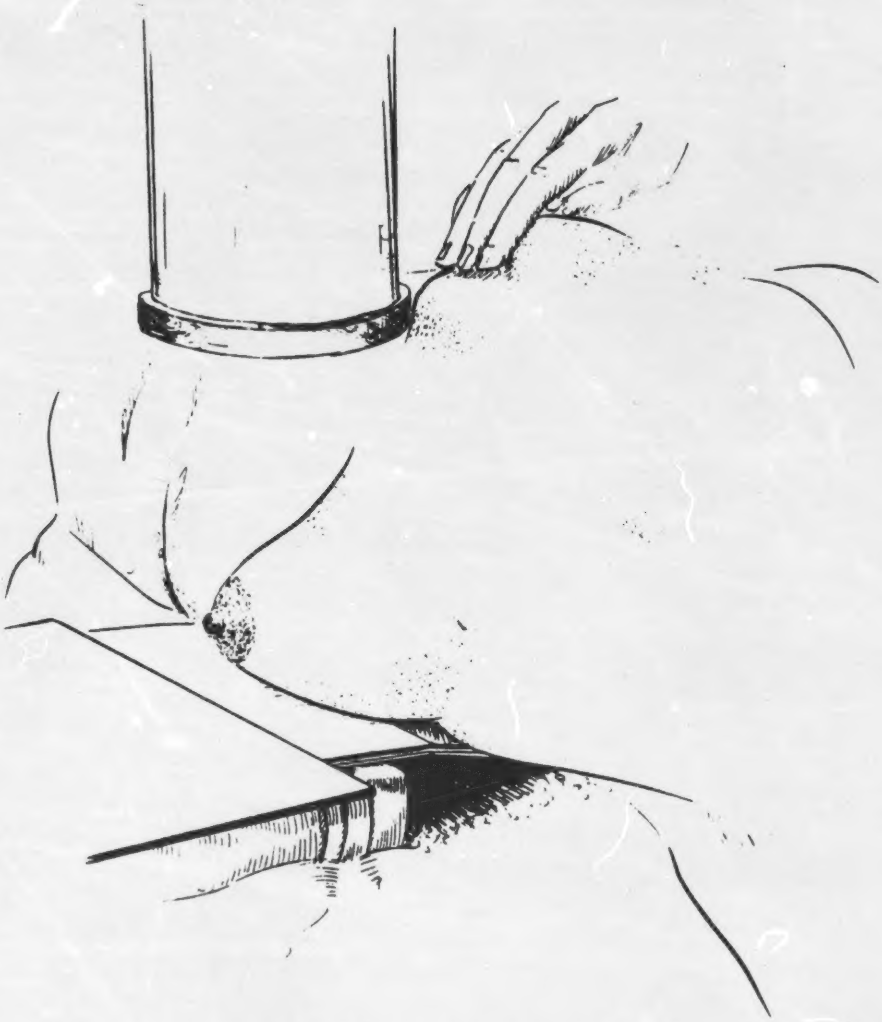


Figure 1-8. Mediolateral projection of the breast.

2. What is the most common cause of detail loss on a mammogram? How can you help reduce this detail loss?

3. What is the normal FFD range used in mammography?

4. Give two advantages and one disadvantage of using a long FFD during mammography.

5. Give an advantage and two disadvantages of a short FFD.

1-3. Mammographic Projections

Three standard projections of the breasts are performed in most radiology departments. They are the craniocaudal, the mediolateral, and the axillary projections. We will discuss each of these, beginning with the craniocaudal.

406. Given a list of statements about the craniocaudal, mediolateral, and axillary

projections of the breast, indicate which are true and which are false.

Craniocaudal Projection. The craniocaudal projection is made with the patient seated at the end of the X-ray table, as shown in figure 1-5. The breast should be positioned so that it is in profile and lies flat on the film, as seen in figure 1-6, A. Elevate the film or adjust the chair so that the patient does not have to raise or lower her chest to achieve the position. She must be seated comfortably; otherwise, she may not be able to maintain the position, and part motion is likely to occur. The patient's chest wall should be in contact with the end of the table to help stabilize her position. Figures 1-6, B, and 1-6, C, show the film positioned too low and too high respectively.

Position the film so that it is against the chest wall. The film position is important because the posterior portion of the breast may not be visualized if the film is improperly placed. Some radiologists prefer the film holder curved down, as seen in figure 1-7. Bending the film has the advantage that the entire breast is visualized but the posterior portion (base) is somewhat distorted due to the angle of that edge of the film.

Make sure that the skin is not wrinkled or folded in any way. These conditions may obscure or suggest pathology and must be avoided. Also be sure that the nipple is in profile. Retraction of the nipple on the radiograph could be an indication of pathology.

Position the patient's arm on the side of the breast being radiographed so that it is relaxed on

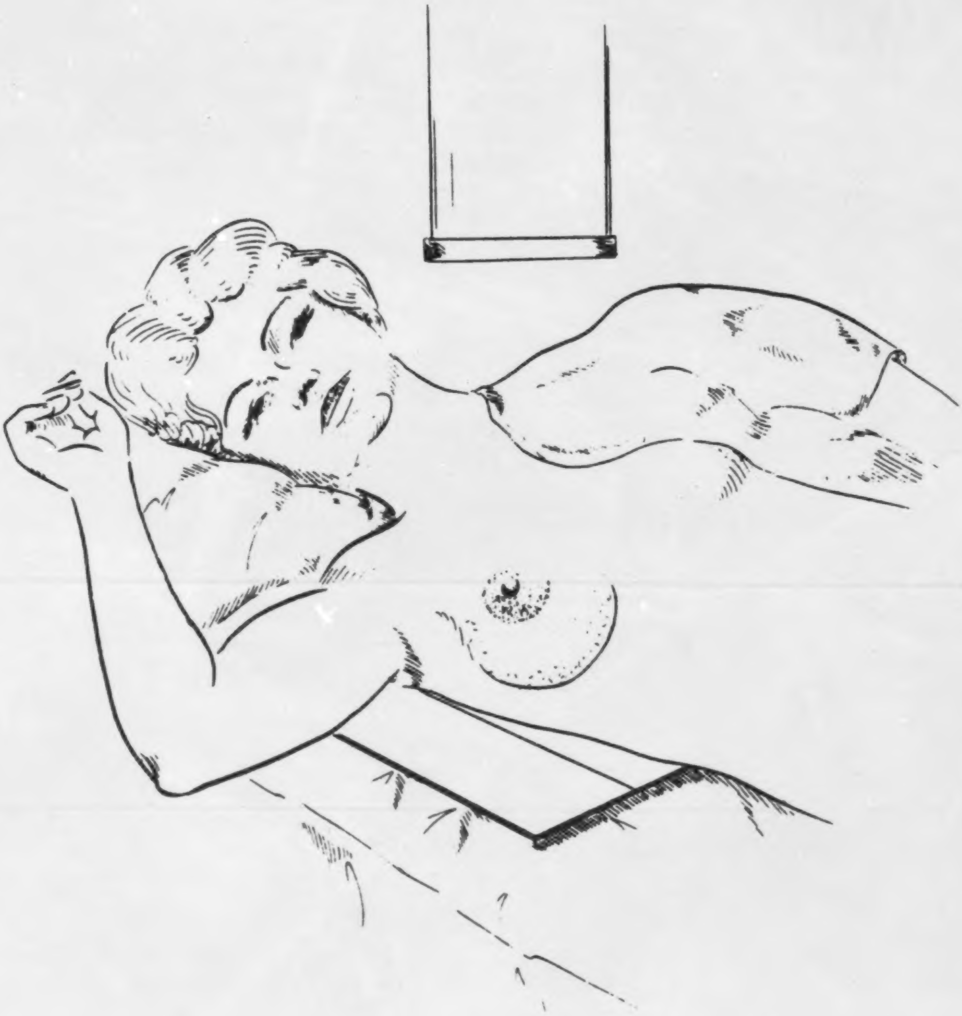


Figure 1-9. Axillary projection of the breast.

the table, as shown in figure 1-5. This allows the full weight of the breast to lie on the film and helps to insure good part-film contact. Also, the hand can be used to maintain the film holder firmly against the chest wall.

One common problem with the craniocaudal projection is that structures superior to the breast are superimposed over the base of the breast. These structures are the clavicle, clavicular and supraclavicular tissue, and glandular tissue of the upper outer quadrant of the breast. The superimposed shadows can best be eliminated by having the patient sit straight in her chair and by pulling her shoulders back. Inspection of the position from above can help you to adjust the shoulders to eliminate the shadows.

Mediolateral Projection. The mediolateral projection is made with the patient in the lateral recumbent position, as seen in figure 1-8. The film is elevated two to three inches from the table, as shown, and placed under the patient so that the chest wall is included on the radiograph. Inclusion of the chest wall helps to insure demonstration of the retromammary space, which visualizes only on this projection.

Rotate the patient so that the breast lies flat on the film and the nipple is in profile to prevent simulation of nipple retraction. Have the patient retract the opposite breast to prevent its superimposition over the breast being radiographed. Disregard for these two procedures is a common mistake with this projection.

Axillary Projection. Make the axillary projection with the patient positioned as shown in figure 1-9. Place the patient's arm at a 90° angle to the body. Rotate her until the tail of the breast is in profile—usually 15° to 30°. Place the film flat on the table and align it to include the axillary area, tail of the breast, and upper outer quadrant.

Exercises (406):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. The breast is positioned so that the nipple is in profile only on the craniocaudal projection.

T F 2. The end of the X-ray table can be used to advantage to prevent part motion on the craniocaudal projection.

T F 3. Distortion of the posterior portion of the breast is caused by bending the film against the chest wall on the craniocaudal projection.

T F 4. Firm contact between the film and chest wall is not important on the craniocaudal projection.

T F 5. Failure to position the breast so that the nipple is in profile could simulate pathology on the radiograph.

T F 6. Dense structures superimposed over the base of the breast may be an indication of improper positioning.

T F 7. The axillary projection demonstrates the tail of the breast.

T F 8. Unwanted shadows can be eliminated on the mediolateral projection by retraction of the opposite breast.

T F 9. The amount of rotation of the patient for the axillary projection depends upon the relative position of the upper outer quadrant.

T F 10. The mediolateral projection is the only radiograph which demonstrates the retromammary space.

Obstetrical Radiography

SUCH PHYSICAL factors as unnatural fetal position, incompatibility of fetal and pelvic signs, and displacement of the placenta, can sometimes present serious obstetrical problems. As you know, evaluation of these complications usually includes radiographic examinations.

Our study of these examinations includes fetography, placentography, and pelvimetry. We begin this chapter with a general discussion of radiation protection for all obstetrical examinations. Following that we will discuss each examination separately.

2-1. Radiation Protection for Obstetrical Patients

You are aware that all patients should be protected from ionizing radiation as much as possible. However, obstetrical patients require special consideration as we shall point out in this section.

407. Answer key questions relating to protecting the obstetrical patient from radiation, patient exposure, and fetal motion.

The Importance of Protecting the Obstetrical Patient from Ionizing Radiation. Ionizing radiation, such as that produced by your X-ray machines, can cause irreversible alterations in the cellular structure of organic tissue. Two types of tissue are highly susceptible to alteration. These two types, gonadal and immature growing tissues, are present in obstetrical patients. Since it is not known precisely how much radiation causes permanent damage to these tissues, you should make every effort to insure that exposure to your obstetrical patients is kept as low as possible.

Patient Positioning. Probably the most common cause of excessive exposure to the patient and fetus is repeat examinations due to improper positioning. The position of the patient for an obstetrical examination, particularly pelvimetry projections, must be "on the money" so to speak. Slight rotation or angulation can prevent accurate evaluation of the radiographs. Be sure to follow the prescribed positioning procedures.

Fetal Motion. Another common cause of excessive patient exposure is repeat examinations due to movement of the fetus during exposure. There are several actions you can take to prevent fetal motion on the radiographs. One such action is to ask the patient to inform you when there is no noticeable fetal movement. Also, have the patient breathe deeply several times and suspend respiration on inhalation before the exposure. Repeated deep breaths hyperaerate the maternal blood and aid in controlling fetal motion.

A short exposure time also should be used to prevent fetal motion. Naturally, the specific exposure time used in your department depends upon several factors, including machine capacity, screen speed, and grid ratio. The point is to use the shortest exposure time possible.

Exposure Factors. Naturally, high mAs and kVp values also contribute to excessive patient exposure. High-speed screens and films should be used so that the mAs and kVp can be kept relatively low. High kVp techniques also reduce patient exposure and should be used as long as the contrast produced satisfies your radiologist. Finally, exposure techniques should be proven and reliable to prevent dark or light radiographs.

Exercises (407):

1. Why is protection of an obstetrical patient from ionizing radiation especially important?

2. Why is obstetrical patient positioning so critical?

3. What is probably the most common cause of excessive exposure to obstetrical patients?

4. Explain three ways fetal motion can be reduced on an obstetrical radiograph.

5. How can exposure factors (other than exposure time) be used to advantage in reducing patient exposure?

2-2. Fetography

Fetography, or a fetogram, is accomplished to demonstrate the fetus. In this section, we will discuss some general radiographic considerations pertaining to fetography and the procedures involved.

408. Given a list of statements about fetography, indicate which are true and which are false.

General Fetographic Considerations. Fetography is performed to detect the presence of a fetus, its age, position, or general condition. Multiple pregnancies are also demonstrated on a fetogram.

Presence of the fetus. A fetogram may be performed to determine whether or not a patient is pregnant. Radiographic indication of pregnancy is, of course, visualization of the fetal skeleton. Usually the first visible parts of the skeleton are the ossification centers for the vertebral bodies, which appear in a curved row. These ossification centers are usually visible at 12 to 16 weeks.

The fetal tissue is more susceptible to alteration by ionizing radiation at this early stage than it is later in the pregnancy. Consequently, it is extremely important for you to produce a good radiograph the first time to avoid the added fetal exposure due to a repeat study. Good detail and sufficient contrast are important because the ossification centers are normally superimposed over the sacrum and fifth lumbar vertebra.

One final word about the presence of the ossification centers. When you are performing quality control duties, look for the vertebrae routinely when evaluating other radiographs made of the pelvic area of procreative patients. You could possibly prevent the newly formed fetus from receiving excessive exposure. This situation can easily occur if the physician does not know that his patient is pregnant.

Fetal age. A fetogram is sometimes performed to determine the approximate age of the fetus. Several parts of the skeleton can be evaluated to estimate maturation. Accurate evaluation of these parts depends upon the detail and contrast on the radiograph. Some of the skeletal parts are difficult to identify even on a high-quality radiograph. Therefore, films of the highest quality are very important in estimating fetal age.

The presence of the distal femoral and proximal tibial epiphyses are an indication of the age of the fetus. They usually appear at the 36th week of pregnancy. Other skeletal parts and the time of appearance are: semicircular canals, 20th week; parietal bones, 20th to 24th week; calcaneus, 20th week; talus, 24th week; cuboid, 40th week; and the femoral head, 40th week in some females. We do not provide you with this information to help you estimate the age of the fetus because your radiologist interprets the radiographs. We mention them to stress the importance of high-quality radiographs, since most of the parts are relatively small.

General condition of the fetus. A fetogram is also taken to evaluate various conditions of the fetus as well as to determine fetal presence and fetal age. These conditions include hydrocephalus (characterized by enlargement of the skull), anencephaly (absence of the skull), and deformed extremities or other parts of the fetal skeleton.

Death of fetus. Fetal death can also be diagnosed on a fetogram. Gas in the fetal circulatory system is a sign of fetal death. The gas usually appears as a thin line of radiolucency—which is very difficult to demonstrate unless the fetogram is of the highest quality. Overlapping of the bones of the skull is another indication of fetal death if the patient is not in labor.

Exercises (408):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. Visualization of the fetal vertebrae is normally the first radiographic indication of pregnancy.

T F 2. Radiographic visualization of the fetus can occur as early as the 20th week.

T F 3. Exposure of the fetus to radiation is equally dangerous whether the fetogram is performed at 14 or at 36 weeks into the pregnancy.

T F 4. Superimposition of other structures over the fetus is of no concern if a fetogram is performed to detect pregnancy.

T F 5. Technicians have no need to recognize a fetus in its early stages on a radiograph unless the radiograph is performed to detect pregnancy.

T F 6. Evaluation of fetal age on a radiograph requires a high-quality film.

T F 7. Distal femoral and proximal tibial epiphyses appear on the fetus at the 36th week of pregnancy.

T F 8. Small bones located in the foot, skull,

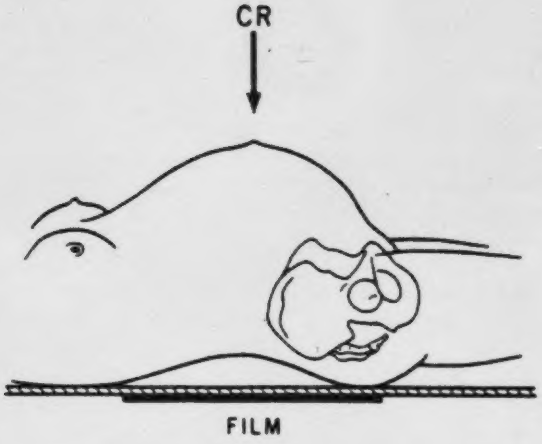


Figure 2-1. AP fetogram.

and hip of the fetus can indicate the age of the fetus.

T F 9. Demonstration of the bones of the skull is not necessary when fetal death is suspected.

T F 10. A fetogram taken to diagnose fetal death must be capable of demonstrating a thin radiolucent line representing gas in the fetal circulatory system.

T F 11. Anencephaly of the fetus is seen on the radiograph as an enlarged fetal skull.

409. Supply missing key words in a list of statements about the performance of fetographic projections.

Projections for Fetography. We cannot tell you what specific projections you should take when performing a fetogram since different radiologists and obstetricians require different projections. We will, however, provide you with the procedures for the most commonly used projections.

AP fetogram. Perform the AP projection in much the same way that you would perform an AP abdomen. See figure 2-1. Center the film for all fetograms to the iliac crests. If the radiograph is taken to detect the presence of the fetus, be sure to include the symphysis pubis since the newly formed fetus may lie low in the pelvis.

PA fetogram. The PA projection is usually considered better than the AP in terms of detail because the fetus is closer to the film on the PA. If the PA is taken to detect pregnancy, include the symphysis pubis for the reason stated above.

There are two ways to position the patient for PA projection. One method is to have her support herself on her knees and forearms and lower her abdomen until the anterior portion of her abdomen is slightly depressed by the tabletop. See figure 2-2. This position causes little discomfort to the patient if performed correctly. Before using this PA projection, be sure to demonstrate the position of the patient.

Another way to position the patient for a PA projection is to place some supportive material, such as pillows, foam positioning blocks, or blankets so that they will be beneath her chest, extreme lower pelvis, and lower extremities. See figure 2-3. In other words, the only area that is not supported is that area over the film. The film is centered to the iliac crest. The height of the support material depends upon the forward extension of the patient's abdomen. If the proper amount of material is used, the patient's abdomen is *slightly* depressed by the X-ray table.

Oblique projections. Normally, an AP or PA projection is sufficient to evaluate the fetus. There are times when a diagnosis cannot be made from

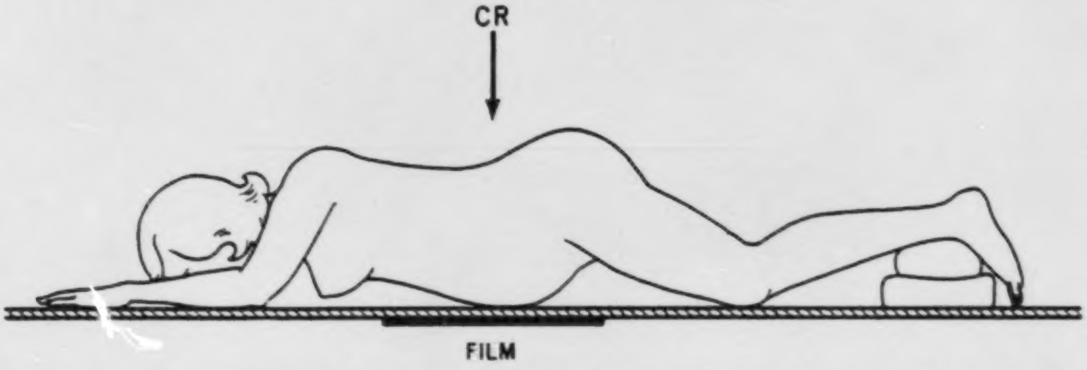


Figure 2-2. PA fetogram (without support material).

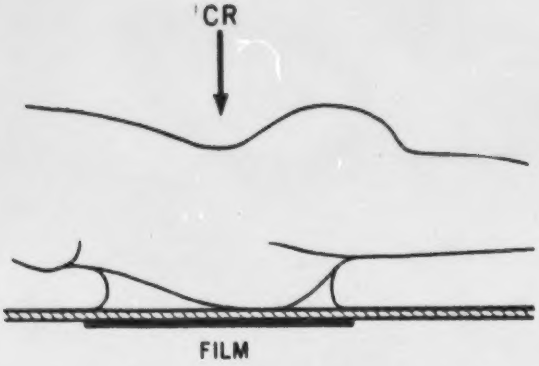


Figure 2-3. PA fetogram (using support material).

either of these two projections because the skeletal parts in question are superimposed over the spine. When this is the case, an oblique projection may be requested by the radiologist. A posterior oblique is usually made if the initial projection is AP, and an anterior oblique is usually made if the initial projection is PA. In either case, the degree of obliquity is determined by the radiologist from the initial radiograph. Be sure to properly support your patient during the obliques to aid in her comfort and to prevent part-motion on the radiograph. The anterior oblique is sometimes called the "position of comfort" because the patient's abdomen shifts to the side and does not support her weight.

Exercises (409):

Fill in each blank space below with one or two key words.

1. The fetographic projection you perform depends upon the requirements of the ________ and of the ____________________ .
2. You should center the film to the ________ ________ when performing a fetogram.
3. If a fetogram is performed to diagnose pregnancy, the ________ ________ should be included in the film.
4. Part-film distance is greater on the ____ than on the _____ projection.
5. A PA fetogram can be performed with the patient supporting herself on her ________ and ____________________ .
6. The ________ projection ________ support material should be demonstrated to the patient.
7. The patient's abdomen is slightly depressed by the table when performing the ________________ projection.
8. If an AP fetogram is made initially, a subsequent projection is probably a ________ oblique.
9. The degree of ________________ for an oblique fetogram depends upon information derived from the ________________ or the ________________ .
10. The anterior oblique is sometimes called the ________________ of ____________ .

2-3. Placentography

Placentography or a placentogram is performed to localize the placenta. We will briefly describe the placenta, discuss the reason for performing a placentogram, and examine the procedures involved.

410. Specify the approximate dimensions of the placenta, its normal location, and a location where it can complicate delivery.

Description and Normal Location of the Placenta. The placenta is a soft tissue mass measuring approximately 20 centimeters in diameter and 5 centimeters in thickness. It establishes communication between the mother and child by means of the umbilical cord. The placenta is normally located on the anterior or posterior uterine wall.

Purpose of Placentography. A placentogram is performed to diagnose a condition known as placenta praevia, a rather serious delivery complication. When this complication is present, the placenta has developed in the lower segment of the uterus.

Exercises (410):

1. What are the approximate dimensions of the placenta?
2. Where is the placenta normally located?
3. Where is the placenta located when it can complicate delivery?

411. Briefly discuss two important factors to consider when performing a lateral placentogram, and state how they should be dealt with.

Radiographic Considerations. Normally, when placenta praevia is suspected, a lateral projection is initially performed since the placenta can be visualized on the lateral in about 90 percent of the cases. If the lateral fails to demonstrate the placenta or shows it located in the lower uterus, an AP projection may be performed.

Lateral projection. While the lateral placentogram on the surface seems simple enough to perform, there are a couple of important factors to consider. One factor that must be considered is that the placenta is a mass of tissue and is nearly equal in density to various other surrounding tissues. Consequently, a soft-tissue technique—relatively low kVp and high mAs—should be used to visualize the placenta. The specific technique should be established after consultation with your radiologist since low kVp and high mAs cause a relatively high absorbed radiation dose to the mother and child.

Another important factor to consider is that the thickness of the maternal abdomen in the lateral position varies considerably from the posterior to the anterior portions. Obviously, you could take two radiographs, using different techniques, to provide the same density over the entire abdomen, but that would expose the patient to twice as much radiation as is actually needed—so two exposures are ruled out. The best course of action is to compensate for the different thicknesses so that one exposure provides the same density over the entire film.

Exercise (411):

1. Name two important factors to consider when performing a lateral placentogram. In each case, briefly explain how the factors should be dealt with.

412. Explain methods of compensating for the uneven thickness of the maternal abdomen.

There are several ways to compensate for the difference in the thickness of the maternal abdomen. One way is to construct a wedge filter to be placed either in the tube port or taped to the collimator. The filter is relatively thick on one end and gradually diminishes to a thin edge on the other end. Place the filter in the primary beam so that the thick edge is over the thinner anterior portion of the abdomen and the thin edge is over the thicker posterior portion of the abdomen. You could achieve the same compensating effect by placing a filter between the patient and the film, but this placement would increase the exposure to the patient and fetus. Consequently, it should not be used.

A wedge-shaped compensating filter can be made from several materials, including aluminum, copper, and barium sulfate. Barium sulfate can be mixed with simple molding clay or petrolatum to provide the proper consistency. The thickness of the filter depends in part upon your machine output. However, a layer of barium paste 2.0 mm thick, decreasing to practically no thickness, spread over a 0.5 mm piece of aluminum, may be expected to provide good compensation.

You can also use a flat piece of aluminum between 1 and 3 mm thick as a filter by placing it in the primary beam over the anterior half of the abdomen. The best place to locate this filter is on the bottom of the collimator.

You can also compensate for the differences in the thicknesses of the abdomen by constructing a special cassette to be used only for a lateral placentogram. Simply cut a pair of fast-speed screens and a pair of slow-speed screens in half, lengthwise. Mount the screens in a cassette so that half the film is exposed by the fast screens and the other half is exposed by the slow screens. When using this cassette, position the "fast" half of the cassette under the posterior portion of the abdomen.

The simplest way to compensate for the thickness differences is to place a 7- by 17-inch piece of opaque paper inside the cassette so that it covers one-half of the film on one side only. This allows that portion of the film to be exposed by one screen, while the other half of the film is exposed by two screens. Place the covered portion of the film under the anterior portion of the abdomen.

Exercises (412):

1. How should a wedge filter be placed in the primary beam with respect to the abdomen?

2. Name three materials which can be used to construct a wedge filter.

3. Briefly explain how to make a wedge filter from barium sulfate.

4. How can a plain, flat piece of aluminum be used as a placentographic filter?

5. How many pairs of what speeds of intensifying screens are needed to construct a special cassette to use for a lateral placentogram?

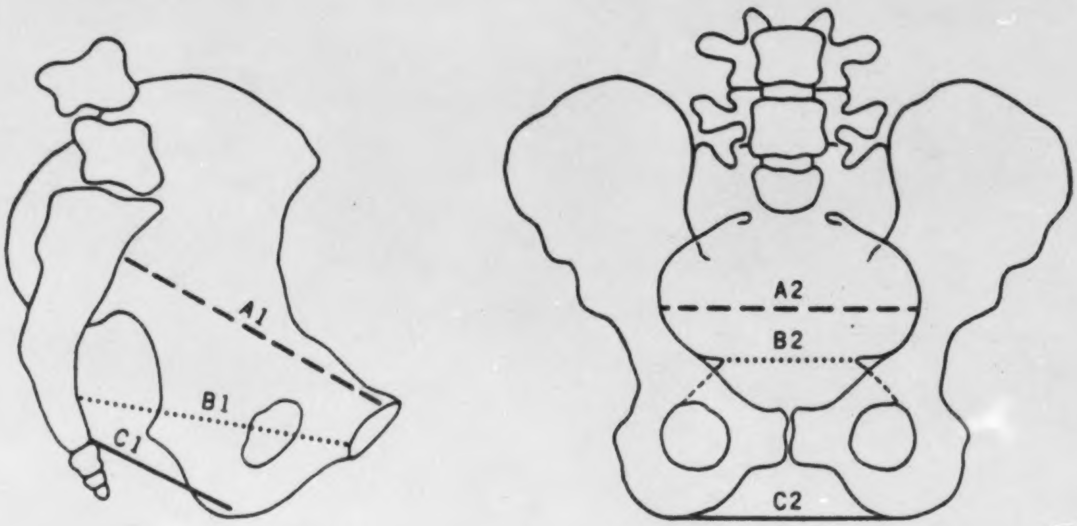


Figure 2-4. Drawings of the pelvis showing diameters measured for Colcher-Sussman pelvimetry.

6. How should the specially constructed cassette be positioned, with respect to the abdomen, for a lateral placentogram?

7. Explain how a plain 7- by 17-inch piece of opaque paper can be used for a lateral placentogram.

413. Explain why an AP placentogram should demonstrate the fetal head and lower maternal pelvis on the film and why the maternal pelvis should be positioned in the true AP position.

AP Projection. If the placenta is not demonstrated on the lateral projection, an AP may be requested. Soft tissue detail is again important, but adequate visualization of the fetal head and lower maternal pelvis is also important. The fetal head and maternal pelvis should be visualized because lateral or superior displacement of the fetal head in relation to the lower maternal pelvis is an indication of placenta praevia. You can understand why the patient must be properly positioned (true AP position) for the AP projection since rotation of the median plane would cause the fetal skull to be projected lateral to the midline.

Exercises (413):

1. Why should an AP placentogram demonstrate the fetal head and lower maternal pelvis?

2. Why should the maternal pelvis be positioned in the true AP position?

2-4. Pelvimetry (Colcher-Sussman)

Normal delivery depends upon various factors, one of which is the relationship between the size of the fetal head and the size of the pelvic opening through which the fetus must pass. Several methods of pelvimetry are used to measure the pelvic dimensions. However, we will limit our discussion to the most common method used—the Colcher-Sussman method.

414. List six diameters that are measured on a Colcher-Sussman pelvimetry, the level of the pelvic opening measured, and the projection it is taken from.

Colcher-Sussman Measurements. We believe that you cannot provide your radiologist with good pelvimetry radiographs unless you know what he wants demonstrated. This statement is valid whether you take the radiographs yourself or evaluate them as a quality control technician. Because of this, we will discuss some of the dimensions your radiologist measures on a Colcher-Sussman pelvimetry.

The measurements are made at three levels of the pelvic opening—the inlet, the midpelvis, and the outlet. Two intersecting diameters are measured at each level, as shown in figure 2-4. Three

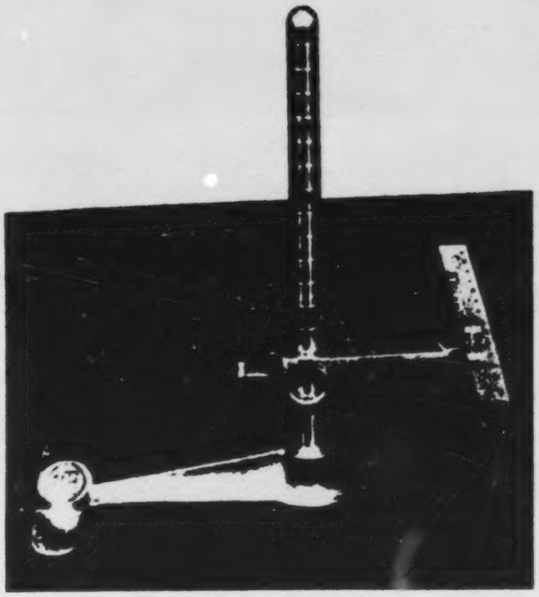


Figure 2-5. Colcher-Sussman pelvimeter.

anteroposterior diameters are measured under lateral projection, and three transverse diameters are measured under the AP projection. In figure 2-4, A1 and A2, are the diameters of the inlet, B1 and B2 are the diameters of the midpelvis, and C1 and C2 are the diameters of the outlet.

Exercise (414):

1. List six diameters that are measured on a Colcher-Sussman pelvimetry. After each diameter, indicate the level of the pelvic opening measured and the projection it is taken from.

415. Specify why the Colcher-Sussman pelvimeter is used, and where and why it is placed on the lateral projection and the AP projection.

Colcher-Sussman Pelvimeter. Since the size of the pelvis and, consequently, the distance between the pelvic diameters and the film, vary from patient to patient, there must be some way to determine the degree of magnification of the diameters on the radiographs. The degree of magnification is determined by the use of the pelvimeter shown in figure 2-5.

Pelvimeter placement. The pelvimeter consists of a base, a vertical cylinder, an arm, and a ruler. The cylinder is marked in 1-cm increments from 5 to 20 cm, and the ruler is 15 cm long and perforated at 1-cm intervals.

When the projections are performed, the pelvimeter ruler is included on the radiographs. On each projection, the ruler is placed at a specific level, which corresponds to the level of the diameter to be measured. For example, on the lateral projection the ruler is placed between the gluteal folds, as shown in figure 2-6. The AP diameters which are measured on the lateral projection are also parallel with the film and located at the same level. In other words, the distance between the ruler and film, and the distance between the AP diameters and film are the same. Consequently, the cm perforations on the ruler are magnified to the same degree as the AP diameters are. See figure 2-7. This built-in compensation allows the radiologist to

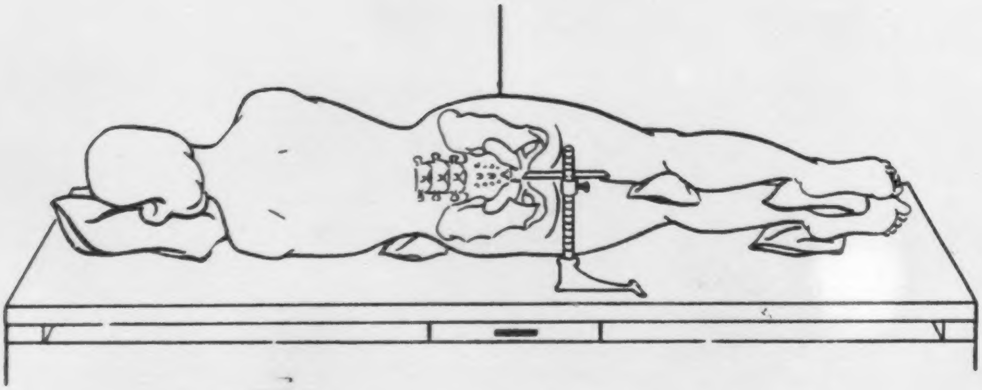
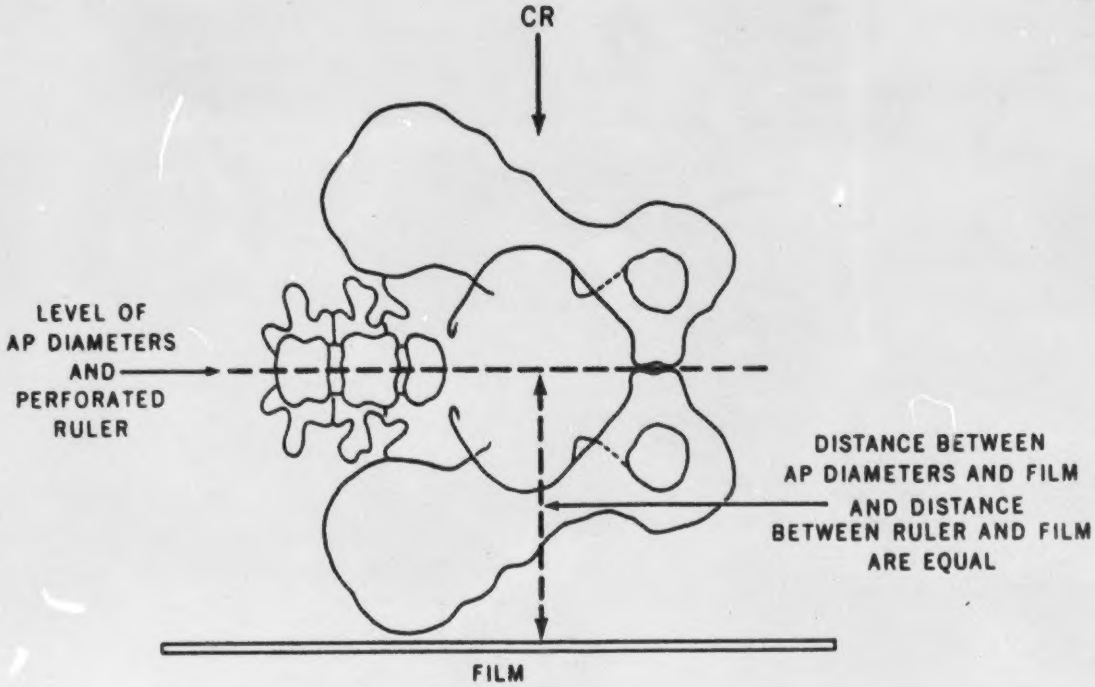


Figure 2-6. Lateral Colcher-Sussman projection showing placement of the pelvimeter.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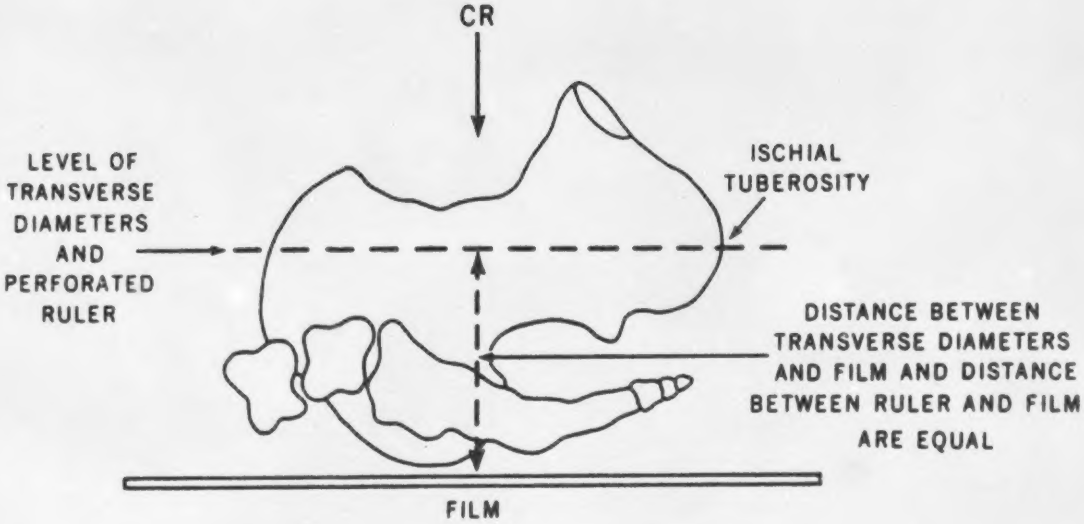
LEVEL OF AP DIAMETERS AND PERFORATED RULER
DISTANCE BETWEEN AP DIAMETERS AND FILM AND DISTANCE BETWEEN RULER AND FILM ARE EQUAL
FILM

Figure 2-7. Illustration showing equal magnification of AP diameters and perforated ruler on the lateral Colcher-Sussman projection.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FILM

Figure 2-8. Illustration showing equal magnification of the transverse diameters and perforated ruler on the AP Colcher-Sussman projection.

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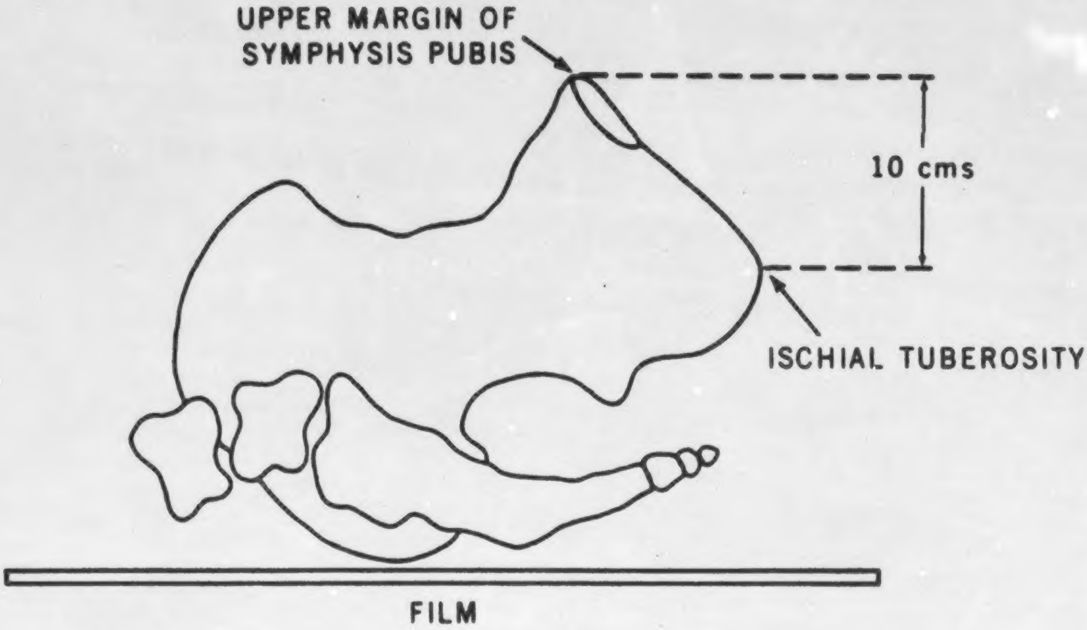

Figure 2-9. How to find the level of the ischial tuberosities by palpating the upper margin of the symphysis pubis.

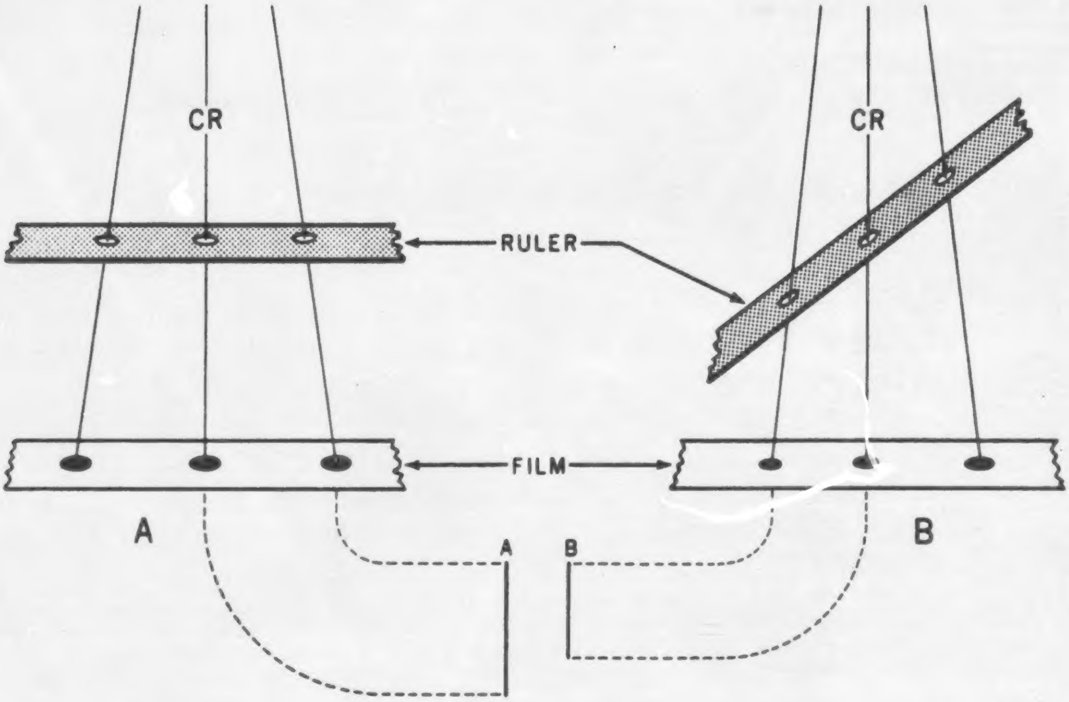

Figure 2-10. Illustration showing the importance of positioning the pelvimeter ruler parallel with the film.

determine the actual diameters even though they are magnified on the radiographs.

For the same reason described above, the ruler is placed on the AP projection to coincide with the level of the transverse diameters. Specifically, the level corresponds to the level of the ischial tuberosities, as seen in figure 2-8. In actual practice, the exact level of the ischial tuberosities is somewhat difficult to palpate. The level can be found more simply by palpating the upper (anterior) margin of the symphysis pubis and setting the perforated ruler 10 cm below that margin, as seen in figure 2-9.

Exercises (415):

1. Why is the Colcher-Sussman pelvimeter used?

2. At what specific location is the pelvimeter placed on the lateral projection and why?

3. At what specific level is the pelvimeter placed on the AP projection and why?

4. Describe a simple method for determining the placement of the pelvimeter on the AP projection.

416. Given specific situations describing positioning of the pelvimeter, explain how and why these positions would affect interpretation of the radiographs.

Importance of pelvimeter placement. To insure accurate evaluation of the maternal pelvis, the pelvimeter must be positioned so that the ruler is parallel with the film. If not, the distances between the ruler "dots" on the radiograph are shortened. Notice in figure 2-10 that the distances between the

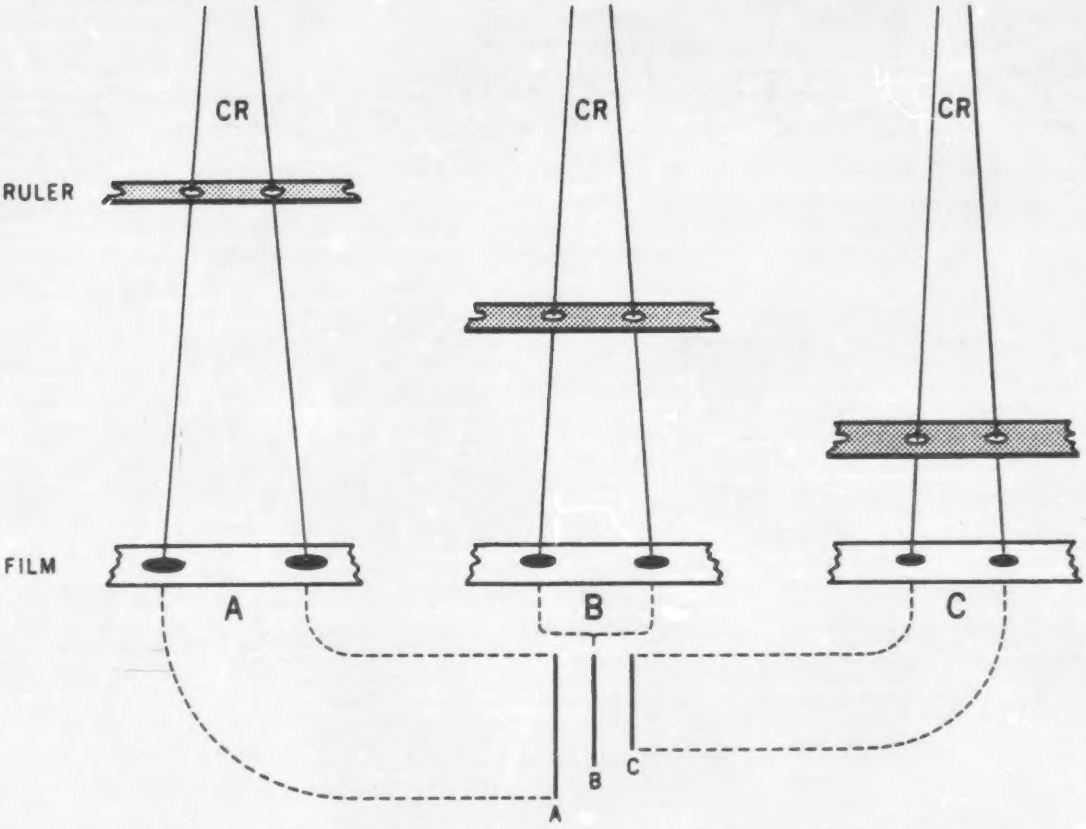

Figure 2-11. Illustration showing the importance of positioning the ruler at the prescribed level of the pelvis.

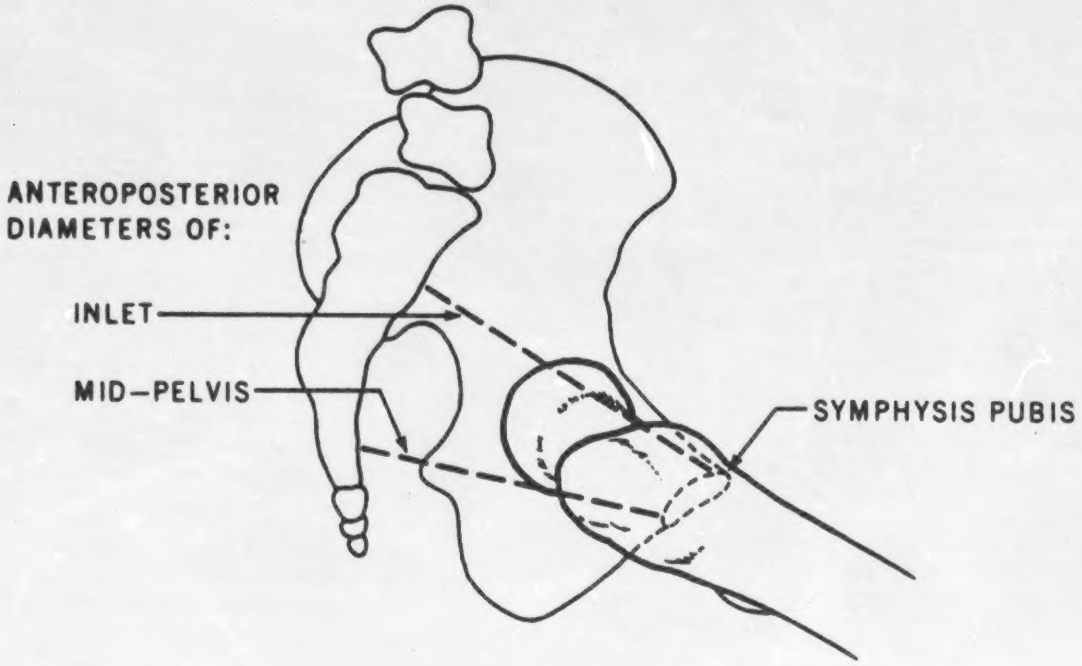

Figure 2-12. Superimposition of the femurs over the symphysis pubis due to flexion of the femurs.

dots on the films are not the same. The dots projected by the ruler in detail B are closer together than those in drawing A, even though the part-film distance is approximately the same. This is due to foreshortening of the ruler. You can see how a nonparallel ruler and film could result in a higher centimeter count for each pelvic diameter and, consequently, the assumption that the diameters are longer than they actually are. The film interpreter might assume that the pelvis is large enough for normal delivery when it may not be.

The pelvimeter must also be placed at the specified level of the pelvis to insure accurate evaluation of the pelvic dimensions. Notice in figure 2-11 that we have illustrated three rulers radiographed, each with a different part-film distance. Consider detail B in the figure to represent the correct level of the ruler for an AP projection. Also, consider details A and C to represent the same AP projections of the same patient but with the ruler higher and lower than normal. Notice that the distances between dots are not the same. This is obviously due to the difference between the magnification caused by the varied part-film distance. If the ruler is closer to the film than the prescribed distance, the effect on evaluation of the diameters is the same as if the ruler and film are not parallel. If the ruler is farther from the film, the diameters are presumed to be shorter than they actually are, and this could lead to the assumption that the pelvis is inadequate for delivery when, in actuality, it may be adequate.

Exercises (416):

1. If, on a lateral projection, the pelvimeter is not placed parallel with the film, how would this condition affect evaluation of the pelvis and why?

2. If, on a lateral projection, the pelvimeter is placed parallel to the film, above the level between the gluteal folds, how would this condition affect evaluation of the pelvis and why?

3. If on an AP projection, the pelvimeter is placed parallel to the film, 7 cm below the upper margin of the symphysis, how would this condition affect evaluation of the transverse diameters and why?

417. Name three common mistakes made when positioning a patient for an AP Colcher-Sussman projection, and state how each mistake affects evaluation of the radiograph and how the mistakes can be avoided.

Common Problems with the AP Projection. Although the AP Colcher-Sussman projection is normally easier to perform, there are some mistakes that are commonly made by technicians.

Rotation of the pelvis. One common error made when positioning the patient for the AP projection is failure to position her so that the median plane is perpendicular to the table. This condition results in a rotated pelvis, which, in turn, obscures the ischial spines and prevents accurate measurement of the transverse diameter of the midpelvis. Also, accurate measurement of the other transverse diameters is made difficult. Check for rotation by measuring the height of the anterior superior iliac spines—they should be equidistant from the table. Also check the greater trochanters—they should also be equidistant from the table.

Missing ruler. The 14- by 17-inch cassette should be centered 1½ inches above the symphysis pubis for the AP projection. This centering point allows ample space on the lower margin of the film to include the ruler. Some technicians have a tendency to center the film higher; consequently, the ruler is not included on the radiograph. Of course, if the ruler is not present, the magnification of the transverse diameters cannot be determined and the radiograph is of no use.

Overexposure. Overexposure of the radiograph occurs occasionally because some technicians measure the abdomen through the thickest portion rather than through the CR where it should be measured. A dark radiograph may prevent the radiologist from identifying the bony landmarks between which he measures the transverse diameters.

Exercise (417):

1. *a.* Name three common mistakes made when positioning a patient for an AP Colcher-Sussman projection; *b.* explain how each mistake affects the evaluation of the radiograph; and *c.* tell how the mistakes can be avoided.

418. Name two common mistakes made when positioning a patient for a lateral Colcher-Sussman projection, and state how the mistakes affect evaluation of the radiograph and how the mistakes can be avoided.

Common Problems With the Lateral Projection. As a general rule, mistakes are more commonly made with the lateral Colcher-Sussman projection than with the PA. Let's discuss the errors.

Anterior rotation of the pelvis. Perhaps the most common mistake made on the lateral is failure to position the pelvis in the true lateral position. More specifically, the pelvis is usually rotated anteriorly—that is, with the side nearer the tube rotated anteriorly. Obviously the rotation shortens the AP pelvic diameters and results in low measurements. This problem is not especially common when the lateral projection is taken erect. When the radiograph is taken with the patient recumbent, she has a natural tendency to assume the previously described position because of the weight of her abdomen. Consequently, careful attention must be given to the patient's position for this projection. Elevate the anterior portion of the abdomen slightly with a wedge-shaped sponge, and superimpose her legs exactly. Also, place supportive material between her knees and ankles to help achieve the true lateral position

Inadequate visualization of the symphysis pubis. Another common error made when the patient is positioned for the lateral is flexion of the femurs to the point where they superimpose the symphysis pubis. Notice in figure 2-12 that the radiologist would have difficulty determining the anterior ends of the AP diameters of the inlet and midpelvis if the symphysis pubis is not visualized, since those two diameters extend to the posterior border of the symphysis pubis. To avoid this condition, extend the femurs when performing the lateral projection.

Exercise (418):

1. *a.* Name two mistakes commonly made when positioning the patient for a lateral Colcher-Sussman projection; *b.* explain how the mistakes affect evaluation of the radiograph; and *c.* tell how the mistakes can be avoided.

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Tomography

CONVENTIONAL METHODS of radiography often result in image superimposition that obscures the structure under study. Sometimes, stereoscopy, tube and film angles, and additional projections may be used to alleviate this condition. However, under certain conditions, tomography may be required to eliminate the superimposition.

Our study of tomography begins with a review of the terminology and types of tomographic systems. After that, we will discuss the principles involved. We will conclude our discussion with some specific tomographic applications.

3-1. Tomographic Terminology, Tube Movements, and Operating Principle

To fully understand tomography, you must be familiar with certain terms. Basic understanding of the various types of tomographic tube movements is also necessary. We shall discuss these subjects in this section and then explain the basic tomographic principle.

419. Define terms pertaining to tomography.

Tomographic Terms. Although there are several names applied to the concept of radiographing a certain section or "slice" of the body, the *International Commission on Radiological Units and Measurements (ICRU)* recommends that *tomography* be used to describe all body section techniques using similar principles. A radiograph produced by these techniques is called a *tomogram.*

A *lever* is a connecting rod which couples the tube and film carrier (cassette tray) so that tube and film movement are proportional. (See fig. 3-1.) The *fulcrum* is the point about which the lever rotates or

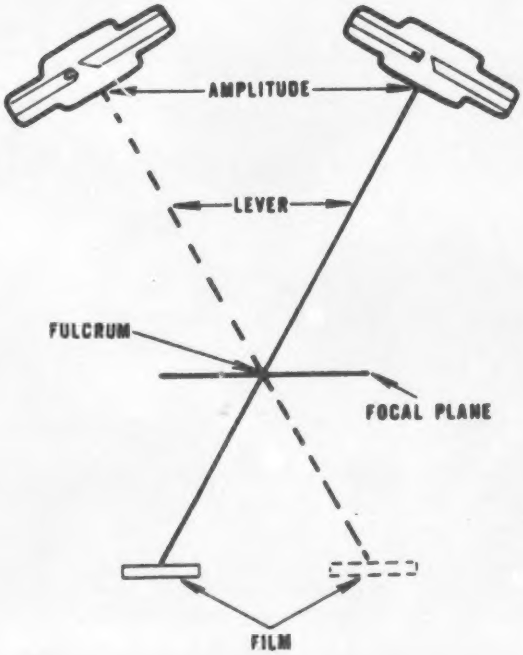

Figure 3-1. Tomographic terms and points of interest.

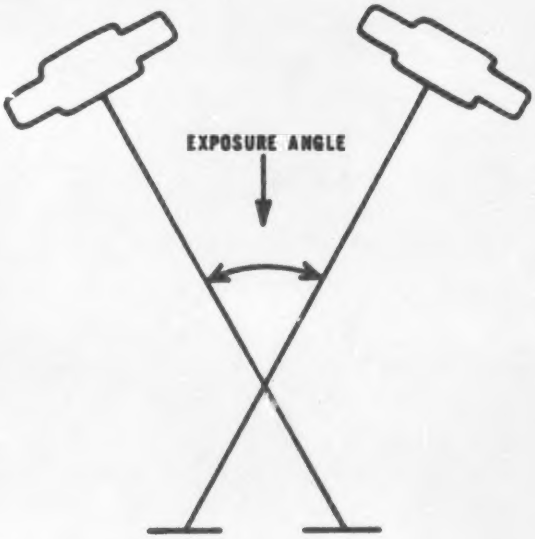

Figure 3-2. Exposure angle.

pivots. When you perform a tomogram, you adjust the fulcrum to correspond to the layer or plane to be radiographed. (See fig. 3-1.)

The *focal plane* (fig. 3-1) is the layer of the body which appears sharpest on the tomogram. You are familiar with the term *blurring*. In tomography, the term represents the unsharp body area outside (above or below) the focal plane.

Amplitude is the distance the tube travels during the exposure—expressed in inches. See figure 3-1. *Rate* is the speed of tube travel—usually expressed in inches per second.

Exposure angle is the angle, in degrees, of the tube travel during exposure. (See fig. 3-2.)

Zonography is tomography with a small exposure angle—less than 10°.

Exercises (419):

Define the following tomographic terms.

1. Tomography.

2. Tomogram.

3. Lever.

4. Fulcrum.

5. Focal plane.

6. Blurring.

7. Amplitude.

8. Rate.

9. Exposure angle.

10. Zonography.

420. Given a figure showing seven tomographic tube movements, identify each movement by name.

Tomographic Tube Movements. The specific movement of the X-ray tube during tomography depends upon the type of system employed. The simplest and most common tube movement is *linear*. During a linear tomogram, the tube moves in a straight line.

A *circular* tube movement is a movement in a complete circle. An *elliptical* movement moves along an oblong circular path. A *hypocycloidal* movement is pretzel-like. *Random* movement follows no specific pattern. *Spiral* tube movement circles toward a central point. Finally, a *sinusoidal* tube movement follows a wavy line.

Exercises (420):

Identify the tomographic tube movements in figure 3-3 by writing the name of the movement opposite the appropriate letter below.

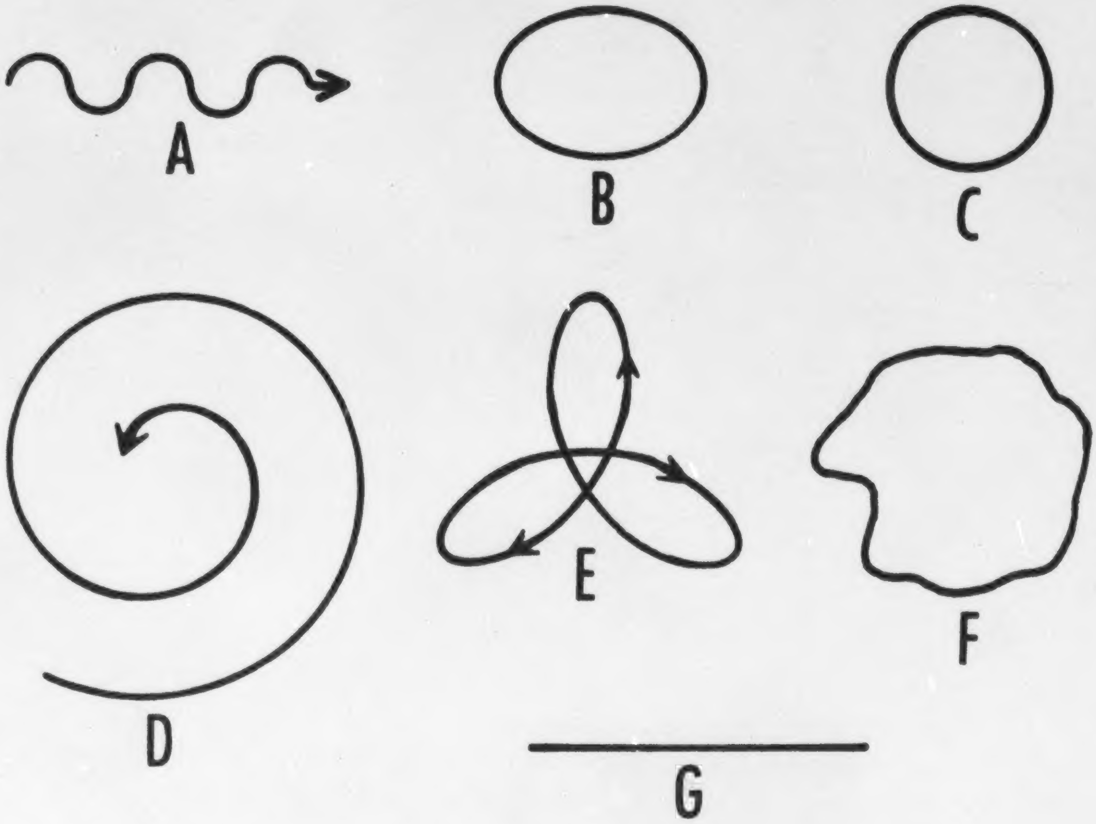

Figure 3-3. Objective 420, exercises 1-7.

1. A.

2. B.

3. C.

4. D.

5. E.

6. F.

7. G.

421. Specify why a structure located at the fulcrum is not blurred on a tomogram, why a structure above or below the fulcrum level is blurred, and the connection between the focal plane and blurring.

Principle of Tomographic Operation. If you perform a PA projection of the chest, the radiograph will show the relatively dense ribs superimposed over particular portions of the lung tissue. If a lesion is present in the lungs between an anterior and a posterior rib, visualization of the lesion is not good because of this superimposition of the ribs.

Blurring. Let's see how tomography can eliminate the rib shadows in a PA projection of the chest, or eliminate various other superimposed structures throughout the body. Figure 3-4 shows five structures in a vertical plane. Assume that circle number three is our lung lesion and circles one and five are ribs. Notice in film position A (the beginning of the exposure) the relative locations of the projected circles. Circle one is projected on the left side of the film, circle number three is projected on the center of the film, and circle number five is projected on the right side of the film.

As the tube and film shift during the exposure, the relative positions of the projected circles, except for circle number three, also shift. When tube movement and film movement stop (film position B), the circles are projected on opposite sides of the film. Notice that circle number one, which was projected on the left side of the film at the beginning of movement, is projected on the right side when movement stops. Positions of circles two, four, and five also change. This change in the projected positions of the circles causes blurring of the images and more or less eliminates them from the radiograph. Projected circle number three remains in the center of the film throughout the movement and is not blurred. Consequently, our lung lesion is visualized without the superimposed shadows of the ribs.

Absence of blurring in the focal plane. Recall that at the beginning of this chapter we defined focal plane as the layer of the body which appears sharpest on a tomogram. Let's see why images in the focal plane are not blurred. Notice in figure 3-5 that the three circles are projected to the same relative locations on the film during the tube movement and film movement. Consequently, the three circles are clearly projected on the radiograph.

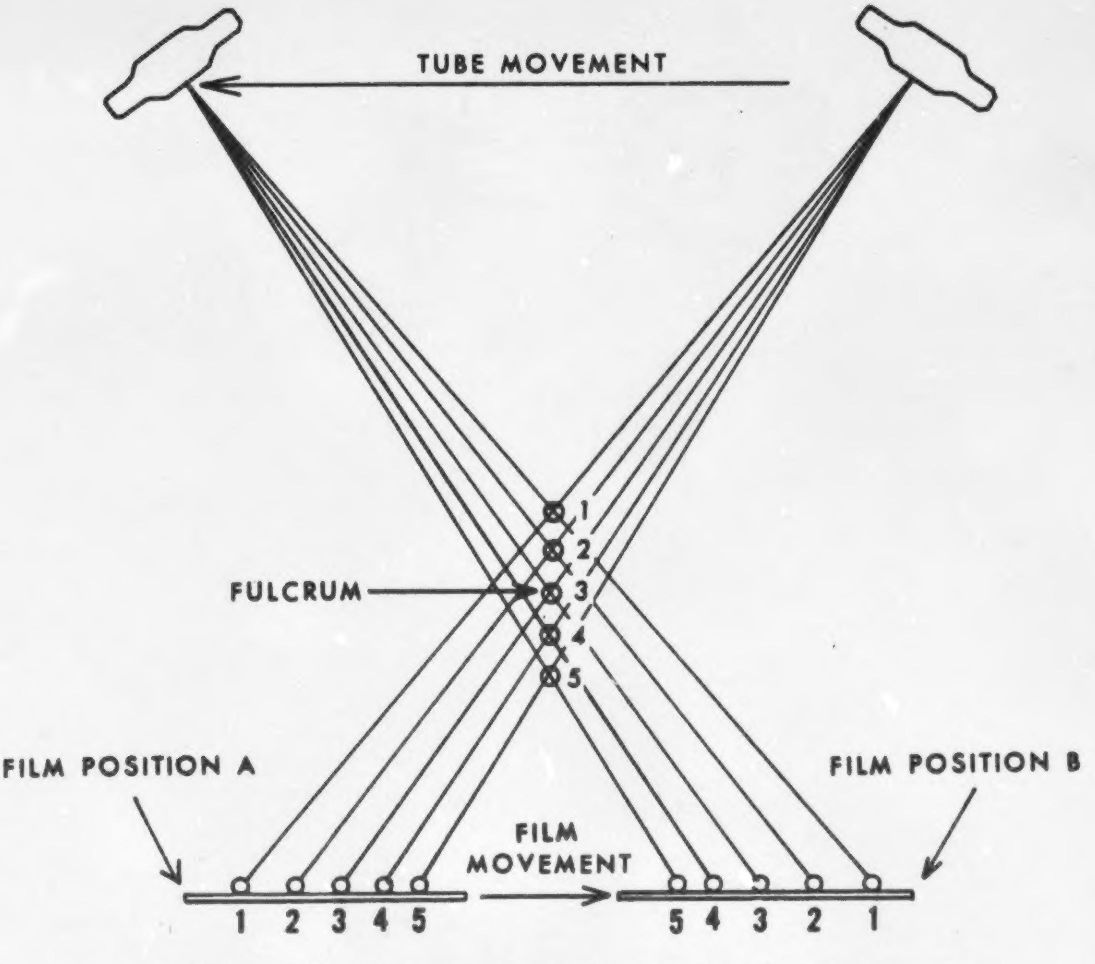

Figure 3-4. Illustration showing why some structures are blurred and some are sharp on a tomogram.

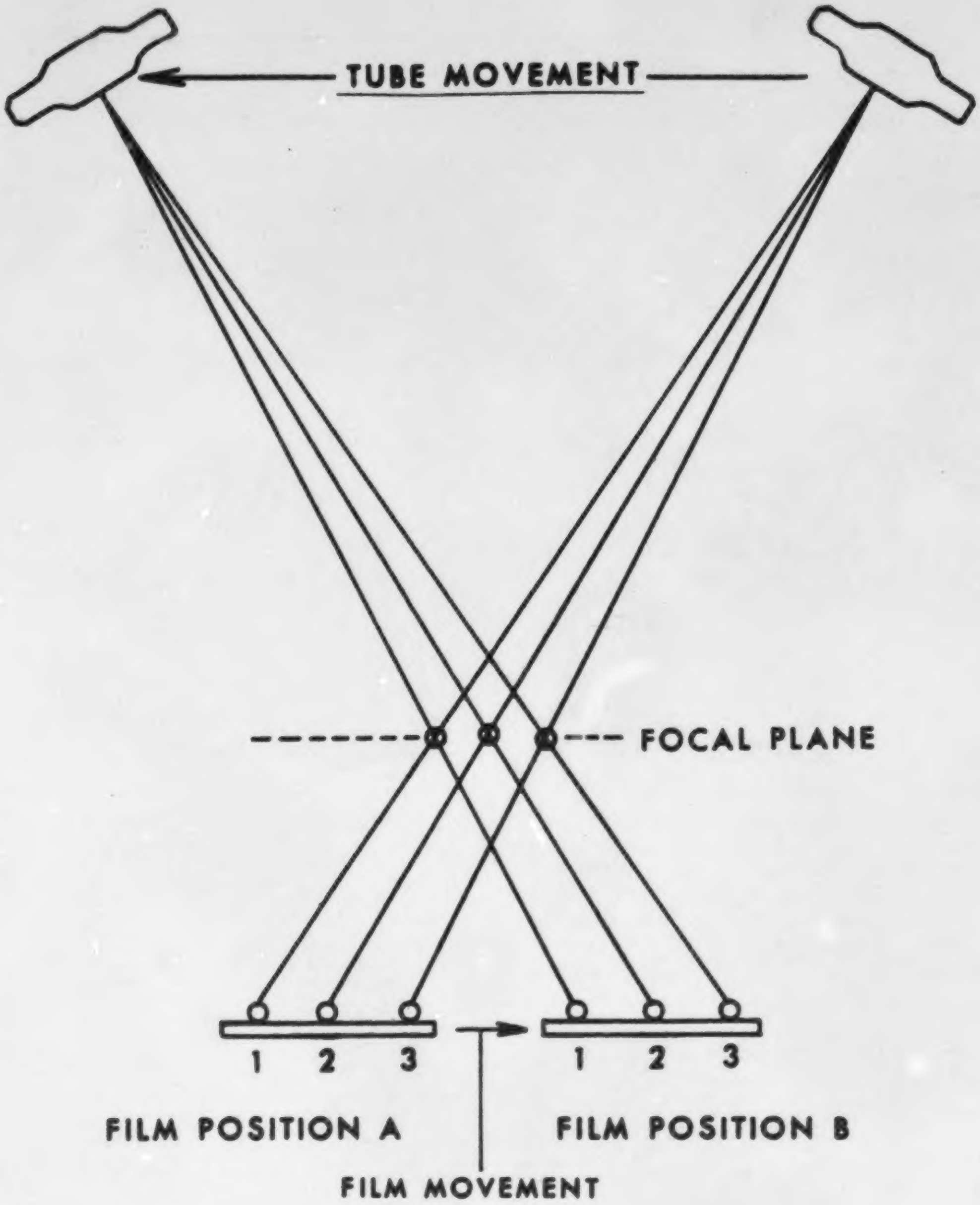

Figure 3-5. Illustration showing why structures located in the focal plane are not blurred.

Exercises (421):

1. Why is a structure located at the fulcrum not blurred on a tomogram?

2. Why is a structure located above or below the fulcrum level blurred on a tomogram?

3. Explain the connection between the focal plane and blurring.

3-2. Section Thickness

Now that we have studied the reasons for the sharp and blurred images on a tomogram, let's dis-

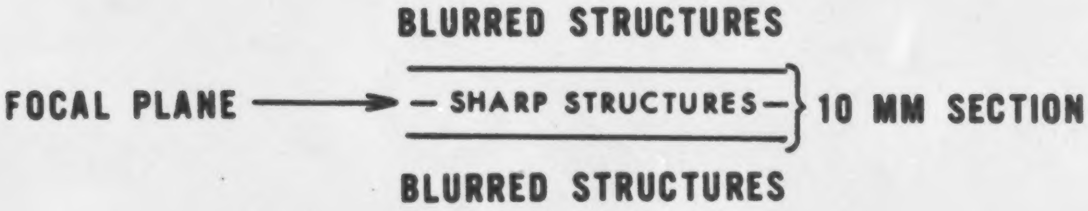

Figure 3-6. Diagram of section thickness.

cuss the thickness of the section and the factors affecting it.

422. Supply key words in a list of statements concerning section thickness and the effect of exposure angle on section thickness.

Description of Section Thickness. When you perform a tomogram, you actually radiograph a layer or section of the body. Generally speaking, everything above and below the section is blurred to the extent that it is not visualized. In actuality, there are no definite lines between the sharp and the blurred images. The degree of blurring gradually increases as the distance from the focal plane increases. By the same token, sharpness increases as the distance from the focal plane decreases.

For all practical purposes, it may be said that there are lines that divide the images that are sharp enough for interpretation from those that are too blurred for interpretation. The portion of the body between those lines is called the *section thickness*. Notice that in figure 3-6 we have illustrated a specific section thickness of 10 mm. All structures within the 10-mm section are considered sharp, while those outside the section are considered unsharp. Naturally, the focal plane is located in the center of the section thickness.

Exposure Angle and Section Thickness. The thickness of the section is not the same for all tomograms. Basically, the thickness of the section depends upon the exposure angle used for the examination. Notice in figure 3-7 that we have illustrated tube movements through two different exposure angles. In detail A, the movement of the projected dots on the film is considerably less than the movement of the dots in detail B. Consequently, there is less blurring with the small exposure angle in detail A. Or, we can also say that the section is thicker with the small exposure angle.

Exercises (422):

Fill in the blank spaces in the statements below with appropriate words.

1. A tomogram records a __________ or ________ _____ of the body.
2. For all practical purposes, there are definite lines which bound the __________________.
3. Structures located within a 5-mm section are _____________, while those located outside the section are ___________________________.
4. A large exposure angle causes __________ blurring than does a small angle.
5. A small exposure angle produces a __________ section than does a large angle.

423. Given a list of statements about the factors affecting exposure angle, indicate which are true and which are false.

Factors Affecting Exposure Angle. Four factors affect the exposure angle:

FFD. If the amplitude is constant, a long FFD produces a thicker section than does a short FFD. Notice in figure 3-8 that both detail A and B show the same amplitude, but due to the difference between the FFDs, the exposure angle is also different.

Amplitude. If the FFD is constant, a short amplitude produces a thicker section than does a long amplitude. Details A and B in figure 3-9 both show the same FFD. The exposure angle is smaller in detail A because of the short amplitude.

Distance of a structure from the focal plane. So far we have discussed the two factors, FFD and amplitude, that affect the exposure angle pertaining to different tomographic exposures. Now let's look at a single exposure and see how the angle changes. Notice in figure 3-10 that the three structures, A, B, and C are projected by different exposure angles, that vary by the number of degrees shown in the figure. Since angle A is greater than angle B, structure A is blurred to a greater extent than structure B. Consequently, we can deduce that the farther a structure is from the focal plane, the more it is blurred.

Distance of a structure from the film. Keeping with a single exposure, the farther a structure is from the film the greater the angle and, consequently, the

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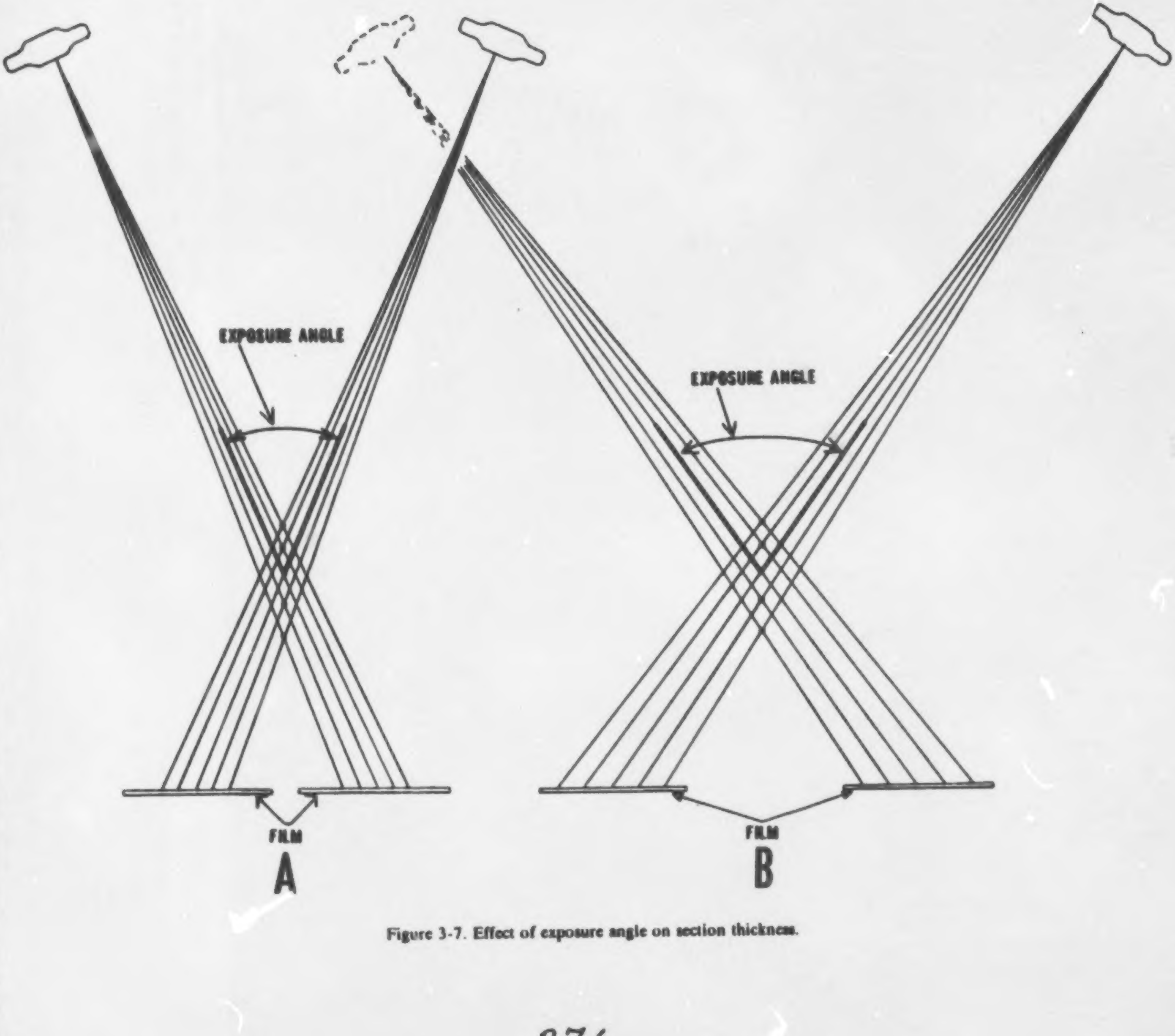

Figure 3-7. Effect of exposure angle on section thickness.

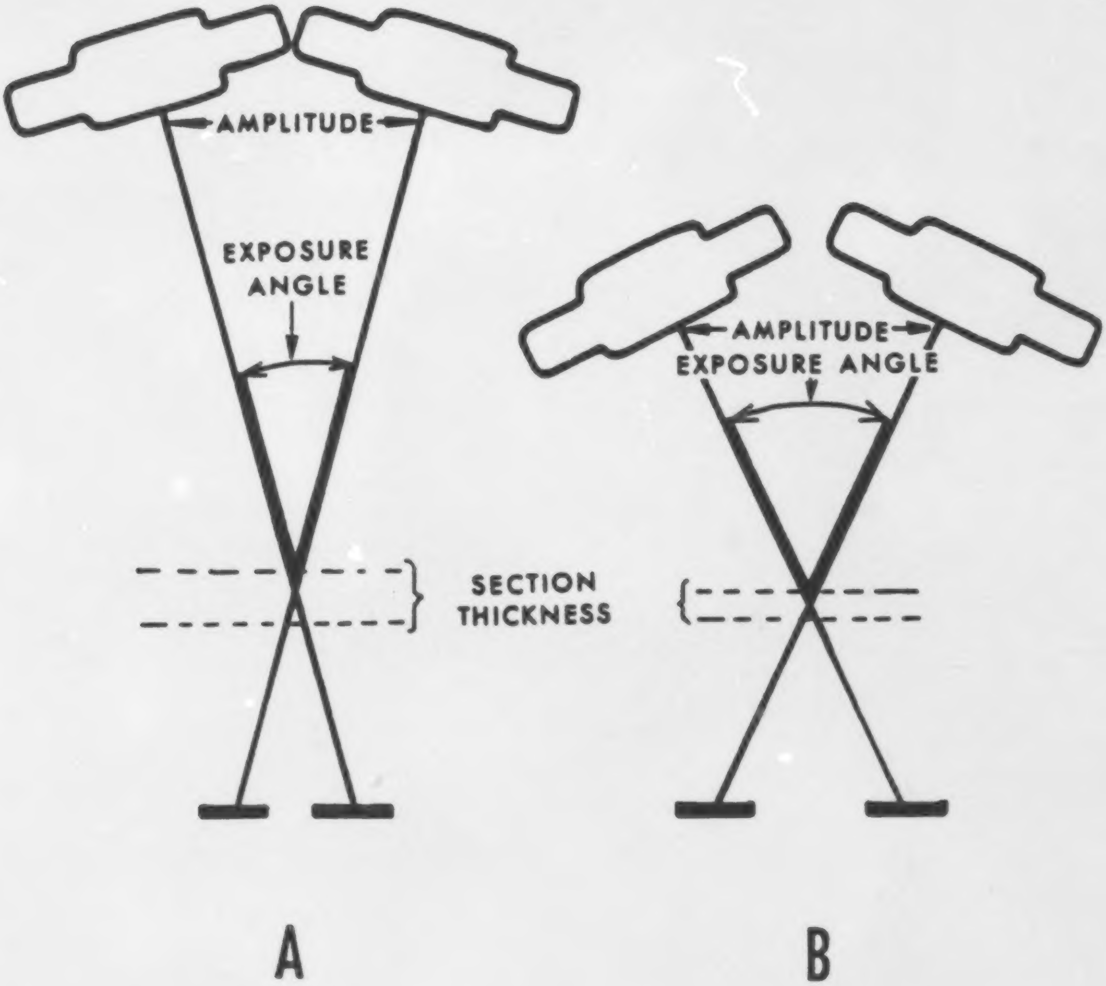

Figure 3-8. Effect of FFD on exposure angle and section thickness.

more blurred it is on the radiograph. As you can see in figure 3-11, angle A is greater than angle C, which means that a structure located at A is blurred more than a structure located at C. Keep in mind that both structures A and B are equidistant from the focal plane.

Exercises (423):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. You should use a short FFD to produce a thin tomographic section.

T F 2. You should use a long amplitude to produce a thick tomographic section.

T F 3. There is no relationship between FFD and exposure angle.

T F 4. On a single tomographic exposure, structures located in the same vertical plane are projected by the same exposure angle.

T F 5. The degree of blurring of a structure is determined by its distance from the focal plane.

T F 6. The exposure angle increases as a structure's distance from the film increases.

T F 7. For increased blurring of a structure, a patient should be positioned so that the structure is farther from the film.

3-3. Multisection Radiography

Multisection radiography is a procedure by which you can perform radiographs of several sections or "cuts" during a single tomographic exposure. There are some definite advantages of using this procedure, as we shall see later in this section. We begin our discussion with a description of the special cassette used during multisection radiography.

424. Give significant details relating to the construction and use of the book cassette.

Book Cassette. Basically, the difference between performing a single tomographic cut and performing several simultaneous cuts is that the latter procedure uses a special cassette called a "book" cassette. The book cassette, illustrated in figure 3-12, has more than one pair of intensifying screens and accommodates more than one film. The exact number of films used in the cassette varies. A five-film book cassette also contains five pairs of screens. If you perform a tomographic examination using a five-film cassette, you produce a cut of a different section on each film. The distance between the cuts is equal to the space between each film in the cassette. For example, if the film interspace is 1 cm, you produce five simultaneous cuts 1 cm apart. Keep in mind that we are not talking about the thickness of the section—thickness is determined by the exposure angle.

The speeds of the five pairs of intensifying screens in a book vary because photons are absorbed as they pass through the films, screens, and interspace material. The top (tube side) pair of screens is slowest, and the remaining pairs are progressively faster. The variable screen speeds compensate for the reduced beam intensity and result in even densities on each film.

Exercises (424):

1. How many sections are radiographed simultaneously with a book cassette constructed with six intensifying screens?

2. Which pair of intensifying screens in a book cassette are the fastest? The slowest?

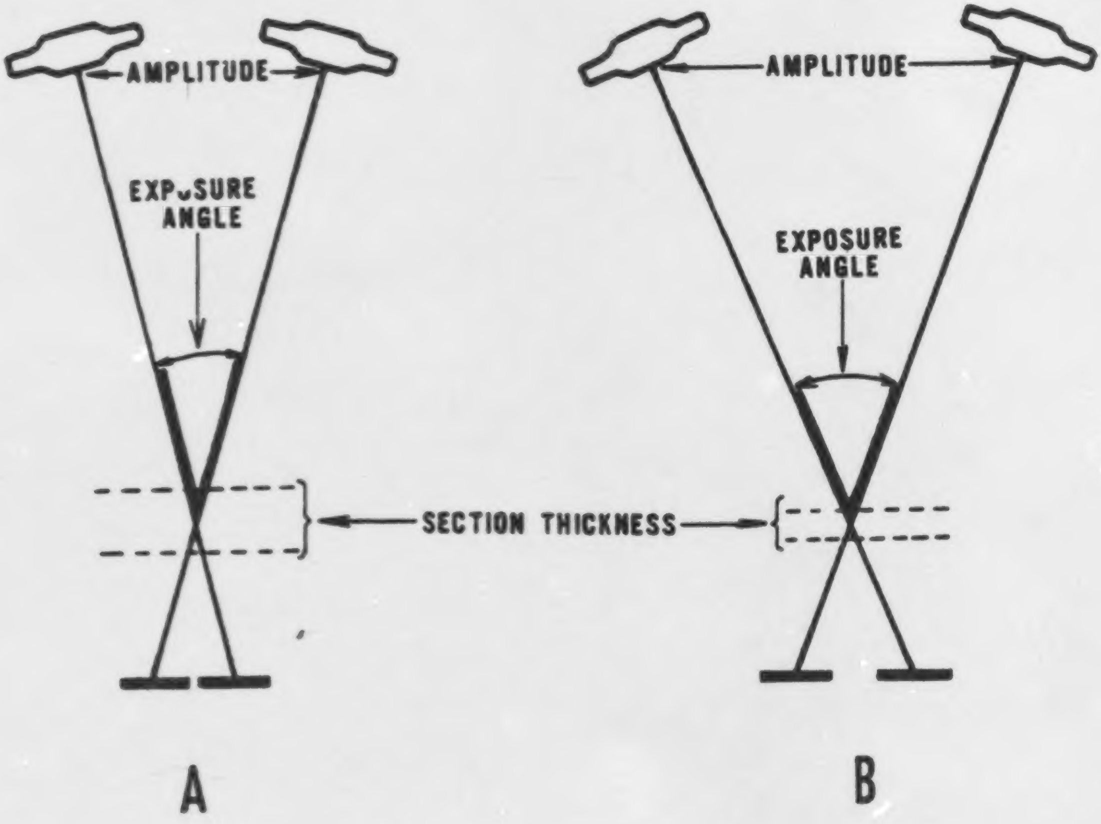

Figure 3-9. Effect of amplitude on exposure angle and section thickness.

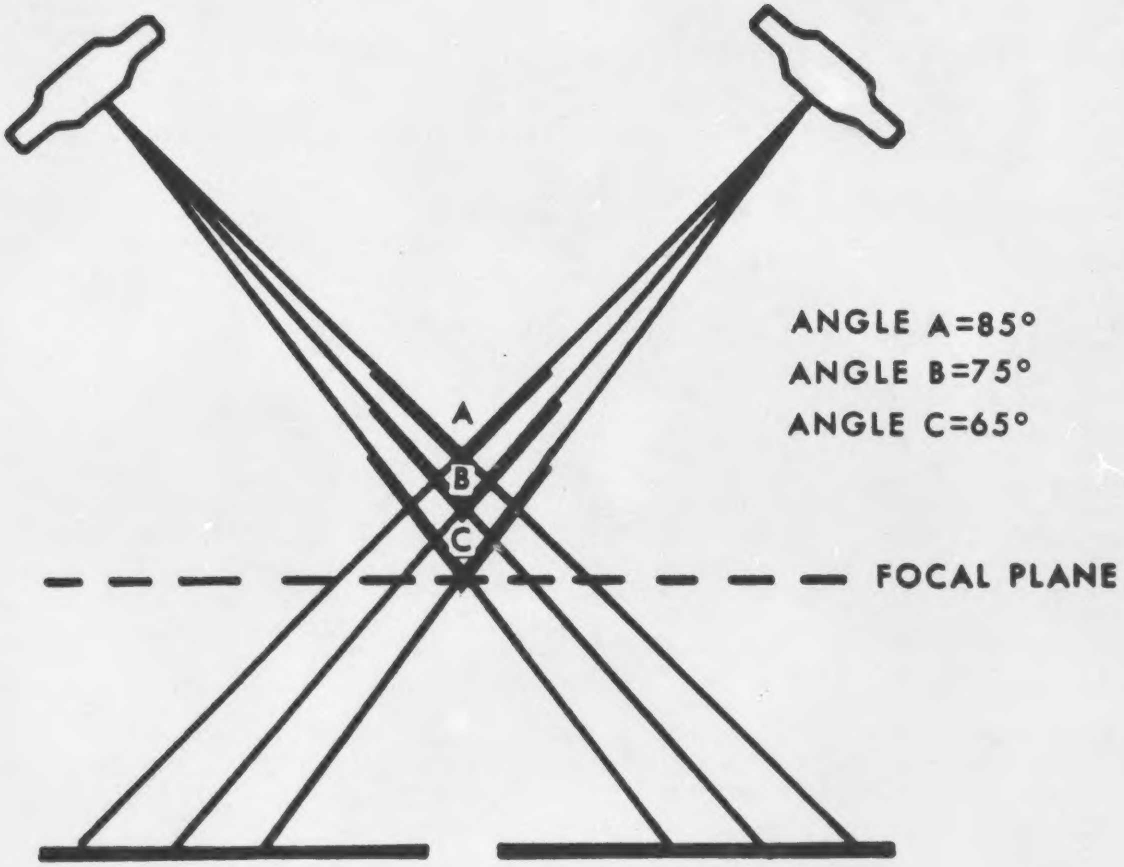

Figure 3-10. Effect of the distance of a structure from the focal plane on exposure angle and blurring.

3. Why do the speeds of book cassette intensifying screens vary?

4. If a book cassette with 0.5 mm of interspace material is used, what is the width of the space between each cut?

425. State why a book cassette records different sections, and—given appropriate information—specify the level demonstrated by the top film and the bottom film of a cassette.

Principle of Operation. The principle of multisection radiography is shown in figure 3-13. Notice that points 1 and 2 in the structure are both projected to the centers of films 1 and 2 respectively. The reason for this is that each film

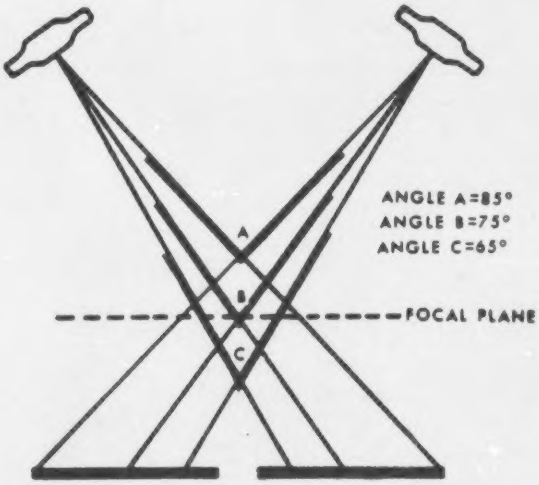

Figure 3-11. Effect of the distance of a structure from the film on exposure angle and blurring.

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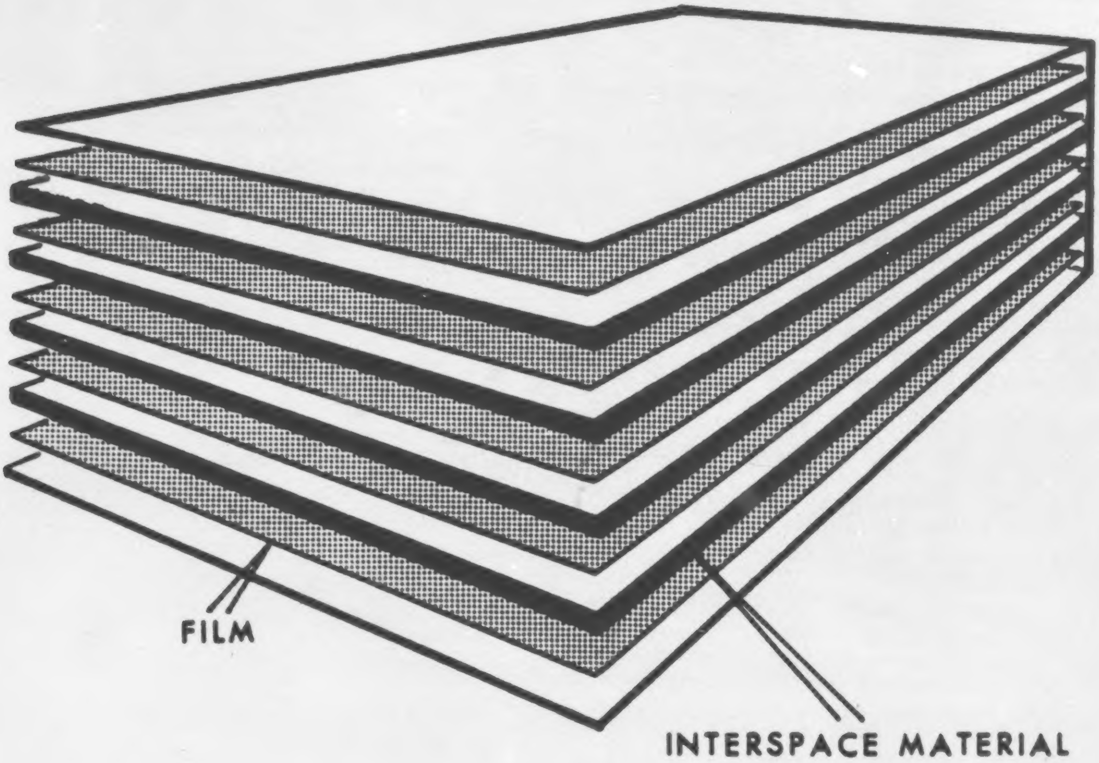

Figure 3-12. A book cassette.

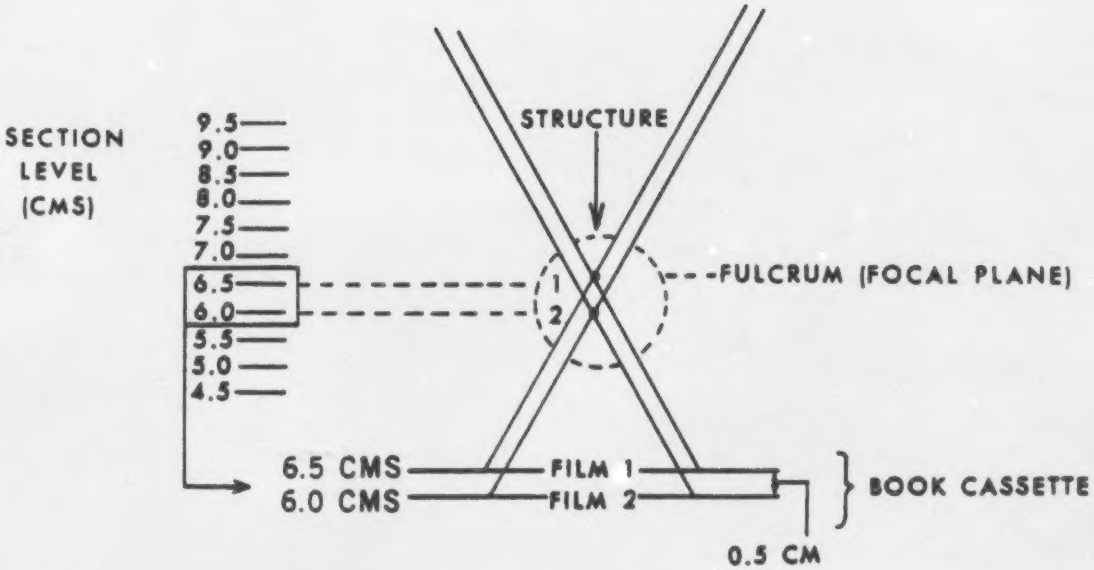

Figure 3-13. Principle of multisection radiography.

has, in effect, its own fulcrum due to the space between the films.

The top film in the book cassette demonstrates the section corresponding to the fulcrum you set on your machine indicator. The second film from the top demonstrates the level below the fulcrum; the third film demonstrates the third level; etc.

Exercises (425):

1. Why does a book cassette record different sections?

2. If a book cassette containing five films and with 1.0 cm of interspace material is used with a fulcrum setting of 15 cm, what level is demonstrated by the top film of the cassette? The bottom film?

426. Answer key questions about the use and the advantages and disadvantages of the book cassette in multisection radiography.

Advantages and Disadvantages. As is true in many areas of radiology, the use of multisection radiography versus single film tomography varies from one radiologist to another. Some radiologists use the book cassette regularly, while others do not use it at all. We will discuss the advantages first, and then the disadvantages.

Advantages. If you make five simultaneous cuts with a book cassette, the patient's dose is less than if you make five individual cuts. Keep in mind, however, that more exposure is required for a book cassette than for a single-film tomogram using a conventional cassette. This is because the exposure for the book is determined by the speed of the top pair of screens, which is usually very slow. Consequently, patient exposure using the five-film book is more than one-fifth of the exposure from five single cuts.

The X-ray tube is subjected to fewer total heat units when a book cassette is used. Obviously, this reduction is due to the relatively low book exposure compared to the combined exposures of the individual exposures.

An advantage which has significance in a busy department is the reduction in the examination time. Depending upon the number of films in the book, it can prevent tying up an exposure room for a long time since, at times, many cuts are needed of a single structure.

Disadvantages. The lower films in a book cassette reproduce a smaller amount of good detail than do the upper films. Obviously, this variation in detail results from the variation in the intensifying screen speed. The lower screens are faster; consequently, detail is not as good.

The fact that the lower films also are subjected to more scattered radiation than are the upper films produces uneven film contrast from one film to another. Both the interspace material and the intensifying screens scatter photons that strike the films. Therefore, the bottom film receives the greatest number of scattered photons.

Exercises (426):

1. Why is the X-ray tube subjected to fewer total heat units when a book cassette is used?

2. If a three-film book cassette is used in lieu of three single cuts, is the exposure to the patient one-third as much? Why?

3. How does the use of the book cassette affect examination time?

4. List and explain two disadvantages of using the book cassette.

3-4. Exposure Factors and Positioning

In this section, we will discuss the difference between conventional exposures and tomographic exposures of the same parts. We will also discuss the relationships between amplitude, rate, and exposure time in linear tomography. We will conclude this chapter with a brief discussion of tomographic positioning.

427. Compare tomographic exposures with conventional exposures.

Tomographic Exposures Versus Conventional Exposures. A tomographic exposure normally should be greater than an exposure of a conventional radiograph, assuming that all other factors, such as projection, part, FFD, etc., are equal. We can best illustrate the reason for the difference with the diagrams in figure 3-14. Diagram A represents a conventional radiograph with a perpendicular CR, while diagrams B and C represent tomography with a small and a large exposure angle. Compare the different thicknesses through which the CR travels for each diagram. Obviously, the more tissue there is between the tube and film, the greater is the exposure required. As a general rule, exposure angles between 20° and 25° require approximately a 50 percent increase in mAs. Zonographic angles require nearly the same mAs, and wide (25° and up) exposure angles require about 100 percent more mAs. The kVp can be regulated as well as the mAs to compensate for the increased thickness. If kVp only is adjusted, use the 50-15 rule explained in Volume 1. In actual practice, both factors are sometimes adjusted.

Exercises (427):

1. If 100 mAs is used for a conventional radiograph, what mAs should be used to tomograph the same part using a 20° exposure angle?

2. If 50 mAs is used for a conventional radiograph, what mAs should be used to tomograph the same part using a 40° exposure angle?

3. Why is more exposure required for tomography with a wide exposure angle than for zonography?

428. Using the appropriate formula, find the amplitude, rate, or exposure time for linear tomography when the other two factors are known.

Amplitude, Rate, and Exposure Time. In pluridirectional tomography (circular, elliptical, etc.), the amplitude, rate, and exposure time are automatically determined when a particular movement is used. With many linear tomographic attachments, you must determine these factors.

The three formulas for determining the factors are as follows:

$$sec = \frac{a}{r}$$

$$a = r \times sec$$

$$r = \frac{a}{sec}$$

where:

sec = exposure time in seconds.
a = amplitude in inches.
r = rate of tube travel in inches per second.

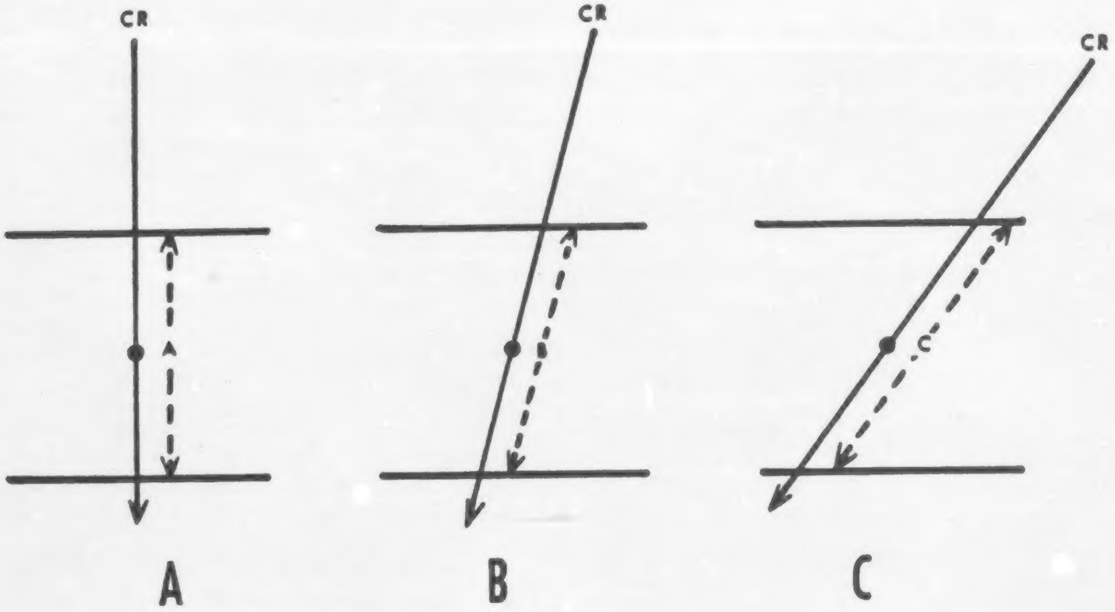

Figure 3-14. Comparison of structure thickness between conventional radiography, small and large angle tomography.

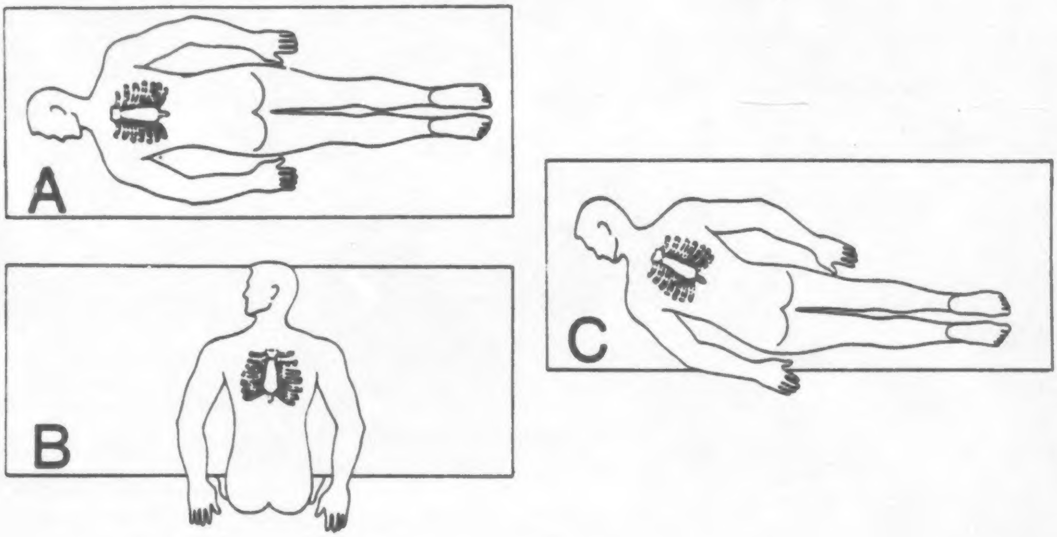

Figure 3-15. Correct and incorrect patient positions for tomography of the sternum.

For example, if the amplitude is 15 and the rate is 10, the exposure time is 1.5 seconds since

$$\begin{aligned} sec &= \frac{a}{r} \\ &= \frac{15}{10} \\ &= 1.5 \end{aligned}$$

Exercises (428):

Using the appropriate formula, find the factor (amplitude, rate, or exposure time) missing from each exercise below.

1. Amplitude: 12 inches.
   Rate: 4 inches per second.

2. Rate: 2 inches per second.
   Sec: 4.

3. Amplitude: 20 inches.
   Sec: 4.

429. Given a list of statements about tomographic positioning, indicate which are true and which are false.

Positioning. For maximum blurring of unwanted structures, the X-ray tube should travel at right angles to the structure's longitudinal axis. For this reason, blurring is particularly effective when using pluridirectional tube movements because the tube moves in many directions and in most cases crosses the longitudinal axis.

Since tube movement in linear tomography is in one direction only, it is important that the patient be positioned, when possible, so that the longitudinal axes of the parts to be blurred are at right angles to the tube movement. Such a position is not always possible, as we shall see in the following example.

If you perform a PA tomogram of the sternum and position the patient as shown in figure 3-15,A, the longitudinal axis of the thoracic spine is in the same direction as the tube travel—consequently, the spine is not effectively blurred. If you position the patient as seen in figure 3-15,B, the spine is blurred because it is correctly oriented to the tube travel, but the longitudinal axes of the ribs are in the same direction as those of tube travel; the ribs are then not effectively blurred. The solution to this dilemma is to position the patient at a 25° to 35° angle on the table (3-15,C).

Exercises (429):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. Pluridirectional tube movements produce better blurring than does a linear movement.

T F 2. Patient positioning is important with linear tomography.

T F 3. For maximum blurring, a part's longitudinal axis should be positioned at a right angle to linear tube movement.

T F 4. The sternum should not be positioned at a right angle to linear tube movement.

CHAPTER 4

Stereoscopic Radiography

ALTHOUGH THE use of stereoscopic radiography as a diagnostic aid has diminished somewhat over the past several years, many radiologists still use it. Some use the examination routinely for certain body parts. Others limit its use to special cases when conventional radiographs do not reveal adequate information or when right-angle radiographs are not possible.

Because stereoscopic radiography is used sparingly in some departments, we, as technicians, have a tendency to become stale in some of the applications. Therefore, our discussion includes a comprehensive review of the tube shift.

As a quality control technician, one of your duties related to stereoscopic films is to insure that the radiographs are performed correctly and, in fact, demonstrate the third dimension. You should evaluate radiographs before sending them to your radiologist. To evaluate the films, you must be able to orient them properly for viewing. Because of this requirement, we will discuss orientation and viewing procedures in depth. Our discussion begins with the tube shift.

4-1. Tube Shift

In this section, we will study the amount and direction of the tube shift for stereoscopic radiography. (NOTE: "Steroscopic radiography" differs from "stereoscopic fluoroscopy," as the names imply. Steroscopic fluoroscopy is not discussed in this chapter.)

Several methods have been established for determining the amount of tube shift. Some are quite involved, requiring various calculations or reference to a chart for each examination. The method described here is simple to apply and produces excellent stereoscopic films if applied correctly.

430. Given selected data (CR, FFD, and tube shift) about stereoscopic radiography, indicate whether or not the data reflects proper procedures.

Amount of Tube Shift. The X-ray tube should be shifted 10 percent of the FFD for all stereoscopic examinations. By tube shift, we mean the *total* shift and not the distance on each side of center. Usually, the tube is shifted one-half the distance on either side of center, as shown in figure 4-1,A. However, you can also shift the tube the entire distance to one side, as seen in figure 4-1,B.

The CR can be directed perpendicularly to the film, as seen in figure 4-1, or it can be angled to the center of the film. To illustrate the reason why you can use an angled CR, we have shown, in figure 4-2, the tube shift distance and the FFD to scale—1 to 10. Notice the broken lines, which represent the portions of the primary beam that strike the center of the film for each tube position. The angles formed by the broken lines and CR are 3° each. The angle formed by these broken lines as they converge to the center of the film is 6°. These angles remain constant at any FFD as long as the tube-shift, FFD ratio is 1 to 10.

Accordingly, you can perform stereoscopic radiographs by angling the tube 3° to the center of the film after the tube is shifted the proper amount to each side of center, as shown in figure 4-3,A. You can also make the first exposure with the tube centered as for a normal radiograph, then shift the tube 10 percent of the FFD in either direction, and angle the CR 6° to the center of the film. (See fig. 4-3,B.)

Exercises (430):

Indicate (yes or no) whether or not the CR, tube shift, and FFD data in exercises 1-4 below reflect proper stereoscopic procedures.

1. FFD 72 inches: CR shifted 3.5 inches from normal tube position for the first exposure and 3.5 inches from the normal tube position in the opposite direction for the second exposure. CR is perpendicular to film for both exposures. ______
2. FFD 36 inches: First exposure made with CR perpendicular to film and in normal tube position. Second exposure made with CR shifted

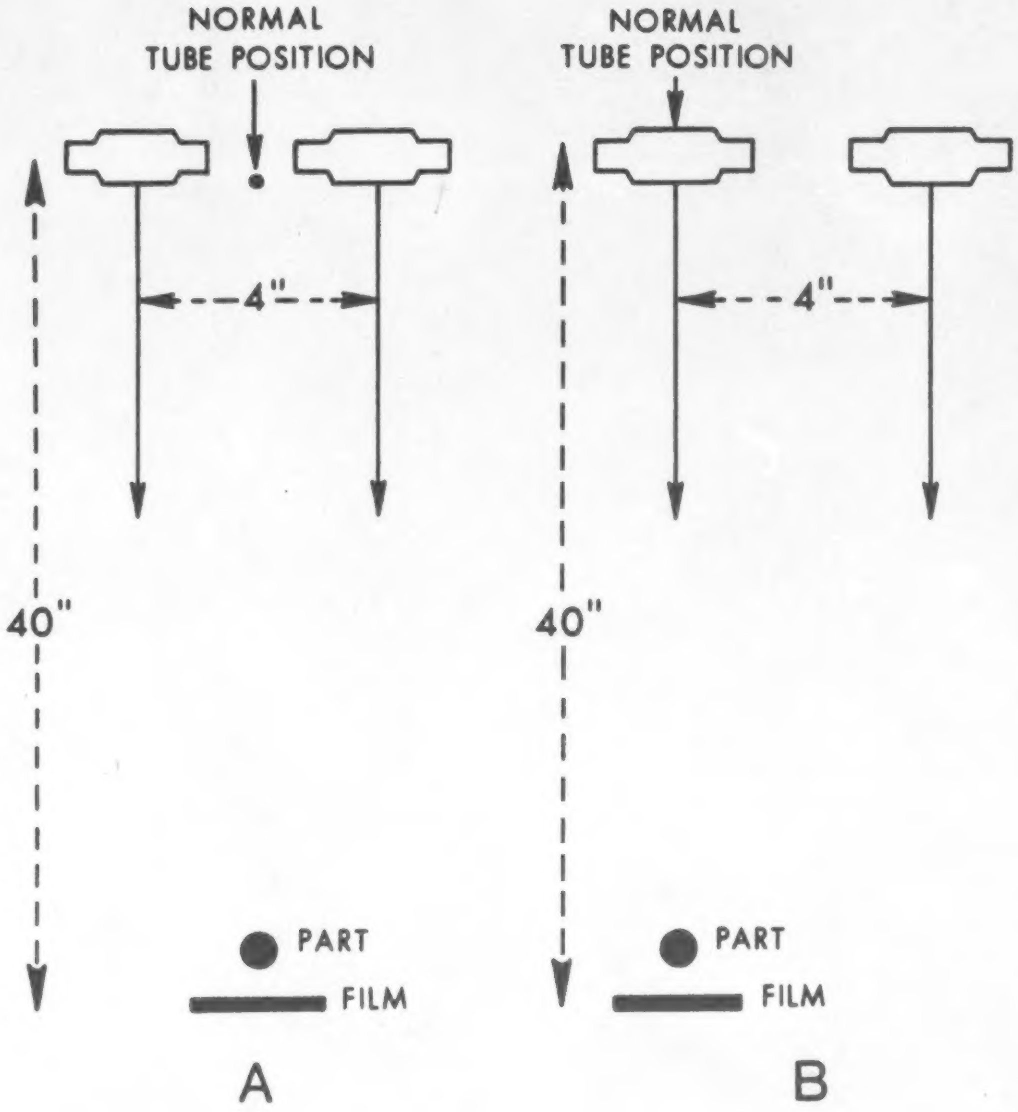

Figure 4-1. Tube shifts for stereoscopy (perpendicular CR).

3.6 inches from normal tube position and angled 3° toward part. ________

3. FFD 40 inches: First exposure made with CR perpendicular to film from normal tube position. Second exposure made with tube shifted 2.0 inches to one side and angled 6° toward part. ________
4. FFD 60 inches: First exposure made with CR shifted 3.0 inches from normal tube position and angled 3° toward part. Second exposure made with CR shifted 3.0 inches from normal tube position in opposite direction and directed perpendicularly to film. ________

431. Give significant details relating to the direction of tube shift for stereoscopic radiographs.

Direction of Tube Shift. For a good stereoscopic effect, the tube must be shifted at right angles to the predominant lines of the part being radiographed. For example, the predominant lines of the femur are along its longitudinal axis; therefore, shift the tube across the longitudinal axis or crosswise. Use the same shift direction for all long bones. (See fig. 4-4.)

The tube is shifted across the predominant lines of a part because that is the direction which produces the maximum variation in the views of the two films; the more variation, the better the stereoscopic effect. Accordingly, general survey stereoscopic PA or AP projections of the skull usually "stereo" better if the tube is shifted across the longitudinal axis. For a lateral, general-survey skull projection, the tube can be shifted either across or along the longitudinal axis of the X-ray table. Since the ribs are the predominant lines of the chest, the tube is shifted with respect to their direction of travel. The individual vertebrae have no predominant lines. Either shift can be used for the pelvis.

A major factor that must be considered when performing stereoscopic projections is grid cut-off due to lateral decentering. You will recall in Volume 1 that we discussed the maximum decentering tolerance for grids with different ratios. It follows that with certain grids you cannot shift the tube across the table. If the tube shift is across the table for a particular stereoscopic examination and the grid ratio is such that lateral decentering is not possible, you can take one of the following actions:

- Replace the grid with one of a lower ratio.
- Remove the grid and perform nongrid radiographs.
- Position the patient crosswise on the table (use a stretcher).
- Shift the tube longitudinally with the table if there is not much difference between the part axes. This works very well with the PA or AP skull.

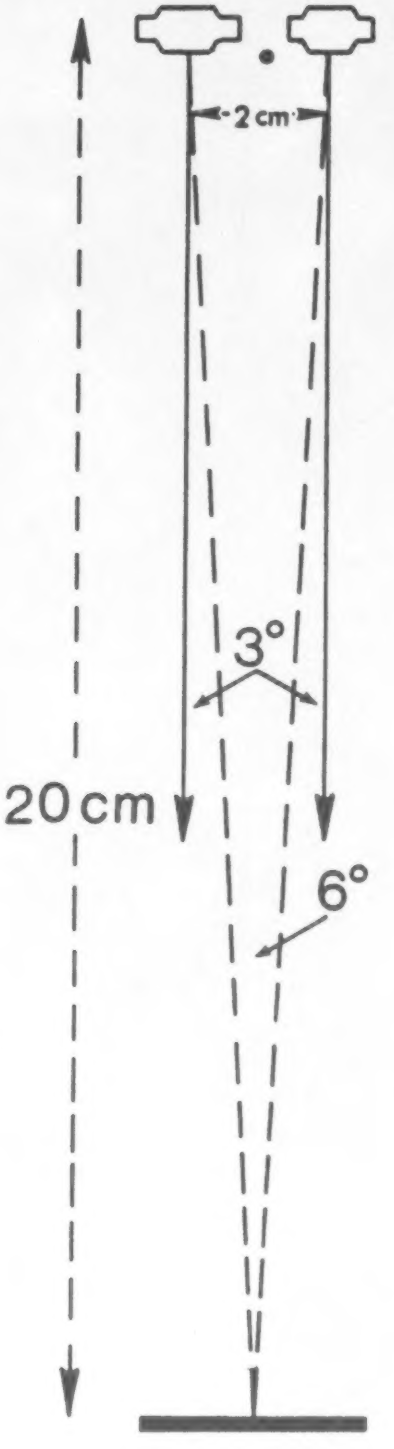

Figure 4-2. Scaled diagram showing actual angles of primary beam exposing the part when a perpendicular CR is used for stereoscopy.

Exercises (431):

1. In what direction, with respect to the part, should the X-ray tube be shifted for stereoscopy?

2. Why is the tube shifted with respect to the part for stereoscopy?

3. If erect PA stereoscopic radiographs are being performed of the chest, in what direction (vertical or horizontal) is the tube shifted and why?

4. In what direction(s) with respect to the X-ray table could the tube be shifted for stereoscopic radiographs of the pelvis?

5. What factor, other than part configuration, must be considered when shifting the X-ray

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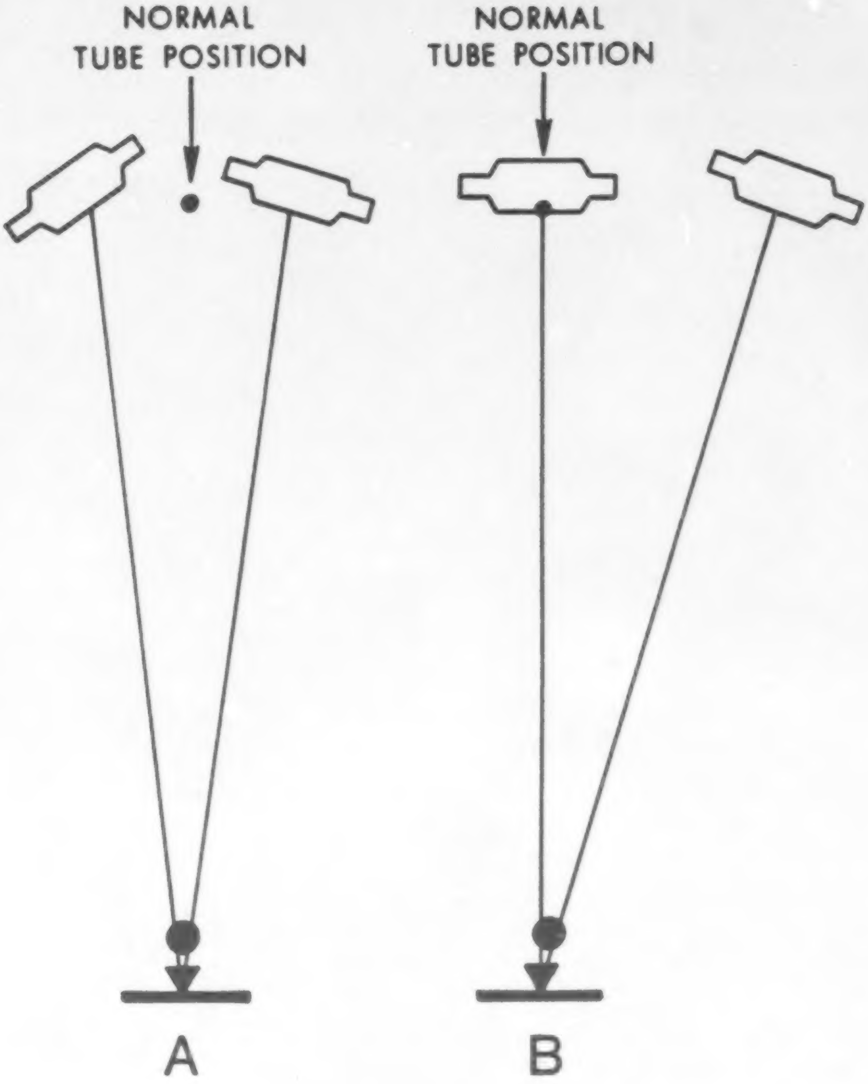

Figure 4-3. Tube shifts for stereoscopy (angled CR).

tube across the longitudinal axis of the X-ray table for stereoscopy?

6. List four possible courses of action you could take if your grid prevents a cross-table shift for stereoscopy.

4-2. Viewing the Radiographs

As we mentioned in the introduction to this chapter, you, as a quality control technician, should evaluate the stereoscopic radiographs before sending them to your radiologist. Evaluation consists of checking the films for density, contrast, etc., as well as determining whether or not the films are in fact "stereo." For this reason, we will discuss stereoscopic viewing procedures in depth.

432. Identify as near or far the relative positions of various specific structures demonstrated on selected stereoscopic examinations when the films are correctly viewed.

Conventional Viewing Versus Stereoscopic Viewing. As you know, we normally view

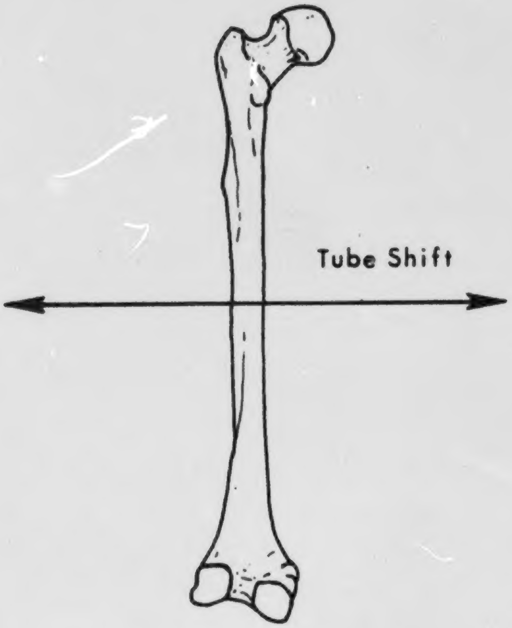

Figure 4-4. Proper direction of tube shift for steroscopic radiographs of a long bone.

conventional radiographs from the film side of the patient. For example, when viewing a PA chest, you see the chest from the front with the patient's right side on your left side. When viewing stereoscopic radiographs, you should view them from the tube side of the patient rather than from the film side. In the case of the PA chest, the anterior ribs and sternum should appear farther from you than the spine or posterior ribs. View lateral stereoscopic projections also from the tube sides. Right-lateral stereoscopic radiographs of the skull should show the right side of the skull farther from you than is the left side, when viewed correctly.

Exercises (432):

In the following exercises, indicate whether the specific structures listed are visualized near or far from you when the stereoscopic examination listed is viewed correctly.

1. PA chest—the thoracic spine.

2. AP pelvis—the coccyx.

3. PA skull—the orbits.

4. Right lateral chest—the right ribs.

5. Left lateral skull—the right orbit.

433. Given a figure presenting photographs of four radiographs, indicate whether you are viewing the radiographs from the tube side of the patient or from the film side.

Determining the Tube Side of Stereoscopic Radiographs. Before you can correctly view stereoscopic examinations, the first thing you must do is to determine the tube side of the radiographs. Obviously, the tube side is the same for both films so the tube side of one is the same as the tube side of the other.

It is relatively easy to determine the tube side of a radiograph if you know whether the projection is AP or PA, and whether a lateral is right or left. Simply consider your eyes as being in the same relative position as the X-ray tube when the film is taken. For example, if you have a PA chest radiograph, the tube "saw" the patient's back; consequently, you are also looking at the patient's back if his right side (the R marker on the film) is on your right side.

If you have a right-lateral radiograph of the skull, you know the right side of the patient's skull was down, or nearer the film. The tube "saw" the left side of the skull. Obviously, if you look at the left side of a patient's skull, his face is to your left.

Exercises (433):

Indicate whether you are viewing the radiographs in figure 4-5 from the tube side or from the film side of the patient.

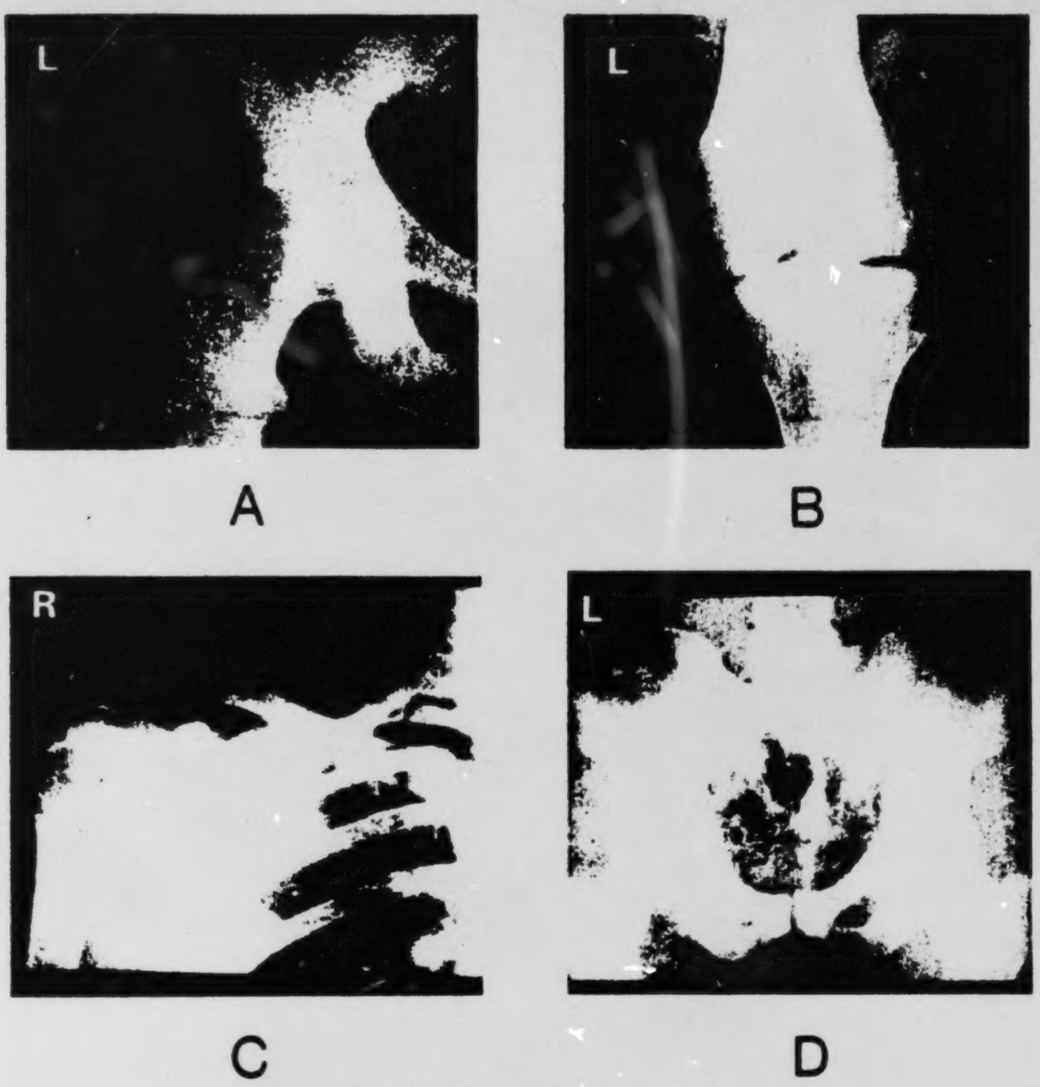

Figure 4-5. Objective 433, exercises 1-4.

1. Figure 4-5,A—PA projection.

2. Figure 4-5,B—PA projection.

3. Figure 4-5,C—AP projection.

4. Figure 4-5,D—AP projection.

434. Given drawings of two superimposed pairs of stereoscopic radiographs, indicate the direction of tube shift for each pair.

Determining the Direction of the Tube Shift. The next thing you must do before viewing stereoscopic films is determine the direction of the tube shift. The direction is either longitudinal or transverse across the part or film.

The simplest way to determine the tube shift direction is to place the films together so that the images are superimposed, as illustrated in figure 4-6. Two edges of each film, A and B in the figure, will be even, while the opposite edges, C and D in the figure, will not be even. The direction of the tube shift is parallel with the even edges, as shown in figure 4-6.

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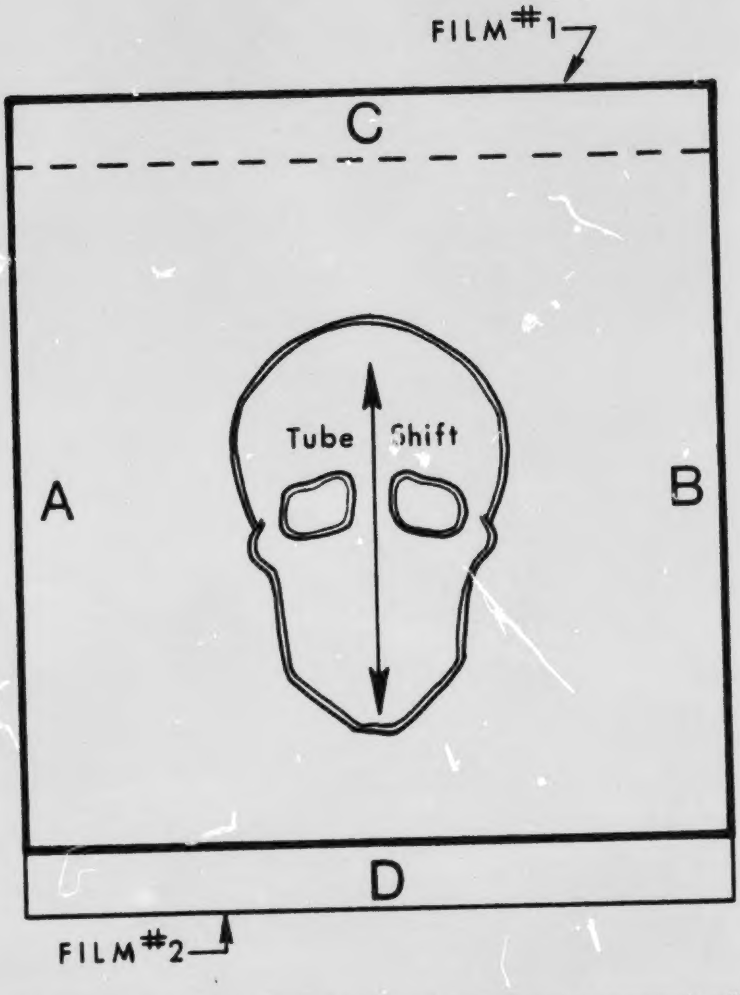

Figure 4-6. Determining direction of tube shift by superimposing images on stereoscopic radiographs.

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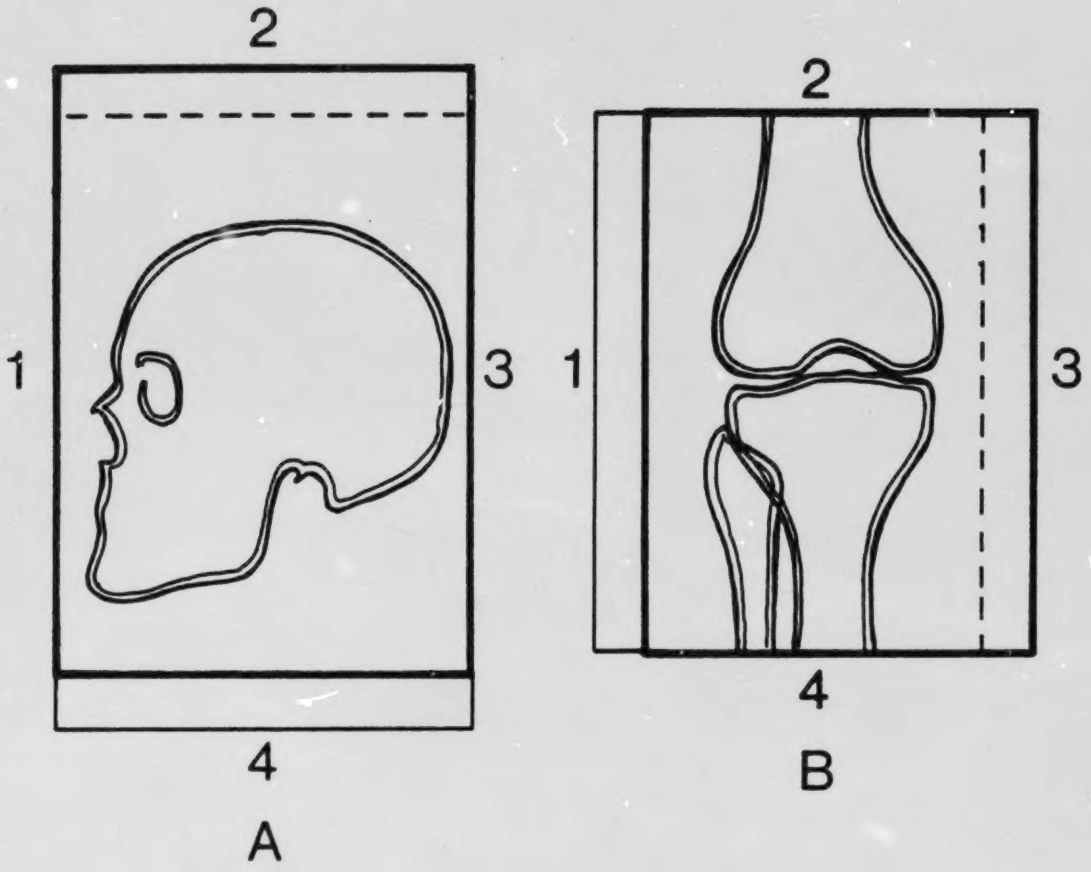


Figure 4-7. Objective 434, exercises 1-2.

Exercises (434):

Indicate the direction of the tube shift for each pair of simulated radiographs in figure 4-7. Indicate the direction with respect to the numbers along the borders of the drawings, either 1-3 or 2-4.

1. Figure 4-7,A. ____________________
2. Figure 4-7,B. ____________________

435. Given drawings of two pairs of superimposed stereoscopic radiographs, indicate which film from each pair is to be viewed by the right eye and which film is to be viewed by the left eye.

Determining the Film Viewed by the Right Eye and That Viewed by the Left Eye. After determining the tube side of the film and the direction of tube shift, the next step before viewing the radiographs is to determine which film is viewed by the right eye and which film is viewed by the left.

The simplest way to determine which film goes with which eye is to superimpose the films, as we did in figure 4-6, to determine the direction of tube shift. In fact, you can determine both factors at the same time. Once you have determined the direction of tube shift with the superimposed films, turn the films, if necessary, so that the axis of the tube shift is horizontal, or parallel with the floor. (NOTE: The axis may already be horizontal—it depends upon how you are holding the films.) The film which protrudes farther to the right (film #2 in fig. 4-6) is viewed by the right eye, and the film which protrudes to the left is viewed by the left eye (film #1 in fig. 4-6). The films in figure 4-6 are identified in this case by rotating them counterclockwise. You could rotate these two films clockwise and end up with film #1 as the right eye film and film #2 the left eye film. In this case, it doesn't matter because both will work. Turning the films clockwise causes you to view the skull with the mandible to your left and turning them counterclockwise you view it with the mandible to your right. If the shift were across the long axis of the part, the direction in which you rotate the film is significant because one direction has the patient standing on his head.

Exercises (435):

Using figure 4-8, indicate which film of each pair is viewed by the right eye and which film is viewed by the left eye.

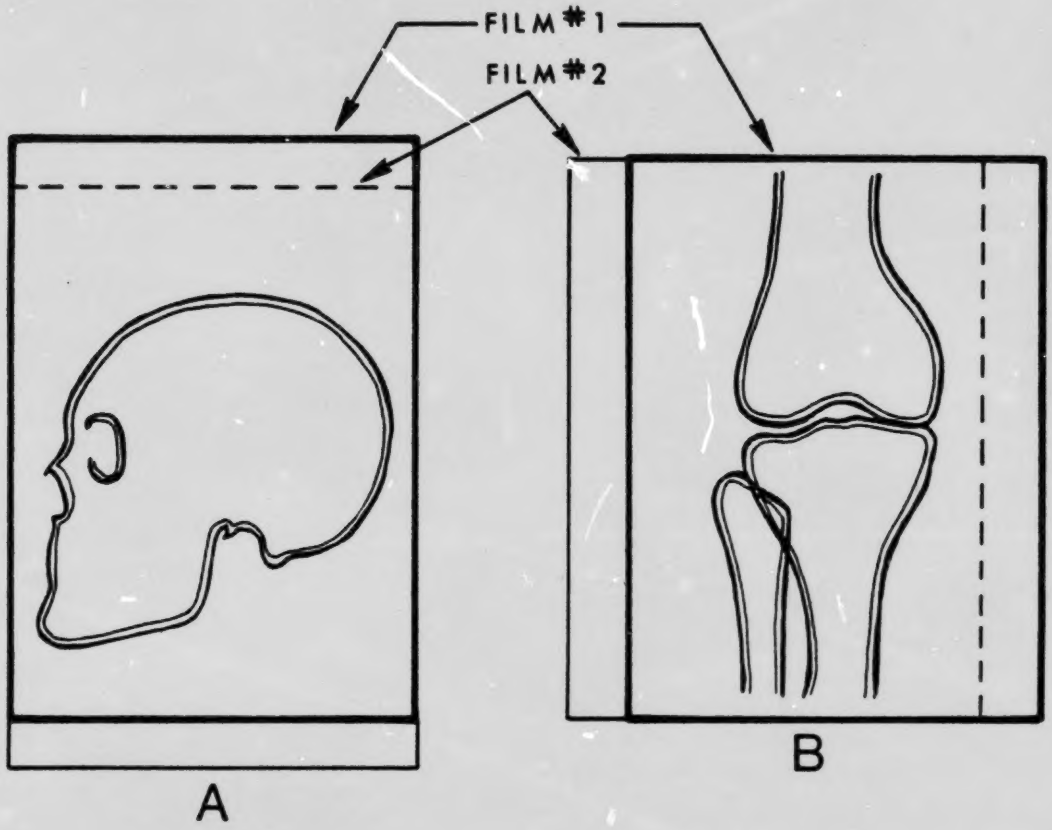


Figure 4-8. Objective 435, exercises 1-2.

1. Figure 4-8,A (rotate counterclockwise).

2. Figure 4-8,B.

436. Supply details that are significant in cross-eyed stereoscopic viewing and in placing films for this method of viewing.

Cross-Eyed Stereoscopic Viewing. We have discussed three preliminary steps that you must accomplish before viewing stereoscopic radiographs. They are determination of: (1) the tube side of the films, (2) the direction of tube shift, and (3) which film is viewed by each eye. Now you should be ready to place the films on the viewboxes for viewing. We will discuss two methods for viewing the radiographs—the cross-eyed and mirror methods.

Principle of cross-eyed stereoscopy. Some technicians can perform cross-eyed stereoscopy and some cannot. Usually, those who view stereo radiographs by crossing their eyes can do so as a result of considerable practice. Some technicians, however, cannot view radiographs with this method even with practice. Our purpose in including this method in this CDC is to familiarize you with this

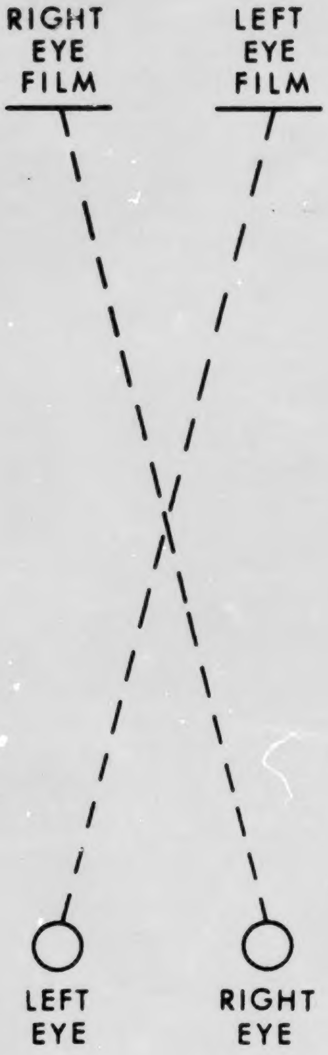


Figure 4-9. Lines of vision for cross-eyed stereoscopic viewing.

type of stereoscopic viewing. It is the most convenient method since you need no special apparatus—only two conventional viewboxes. Crossing your eyes for the time it takes you to view radiographs causes no "permanent" damage to the eyes. Temporary strain or slight pain may occur. If the discomfort bothers you, you probably should not use this method for viewing stereoscopic radiographs.

Basically, when you cross your eyes to view the two radiographs, your right eye sees the film on the left and your left eye sees the film on the right, as shown in figure 4-9. Your eyes converge to a point between you and the films.

Figure 4-10 shows two drawings seen from slightly different angles to represent the different projections obtained in stereoscopy. Check your ability to see depth from two radiographs by crossing your eyes until you see only three structures (initially you will see four). Concentrate on the center structure. You can also hold the point of a pencil slightly below the space between the two drawings and focus both eyes on the tip of the pencil. Move the pencil toward or away from you until you see three structures. Are the two dots inside or outside the structure?

Film placement. When placing the radiographs on viewboxes for cross-eyed stereoscopic viewing, arrange them so that the direction of tube shift is horizontal or parallel with your interpupillary line. Turn the films so that the tube side is toward you. Finally, place the films on the viewboxes so that your crossed eyes see the correct film.

Exercises (436):

1. What apparatus is needed for cross-eyed stereoscopy?

2. Why is cross-eyed stereoscopic viewing advantageous?

3. When you cross your eyes to view stereoscopic radiographs, on which side should the right eye film be placed?

4. When viewing stereoscopic radiographs by crossing your eyes, how should the films be placed on the viewboxes with respect to the direction of tube shift?

5. Which side of the films (tube side or film side) should be against the viewboxes when viewing stereoscopic radiographs using the cross-eyed method?

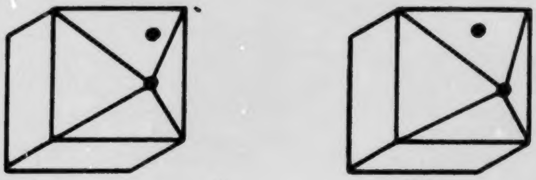
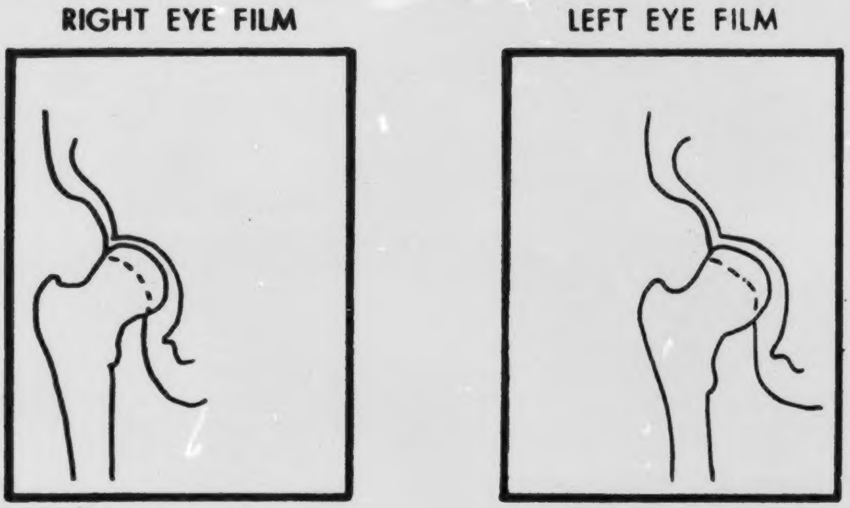


Figure 4-10. Test for cross-eyed stereoscopic viewing.

437. Given drawings of two pairs of stereoscopic radiographs, indicate whether or not each pair is properly placed for viewing with single and double mirror devices.

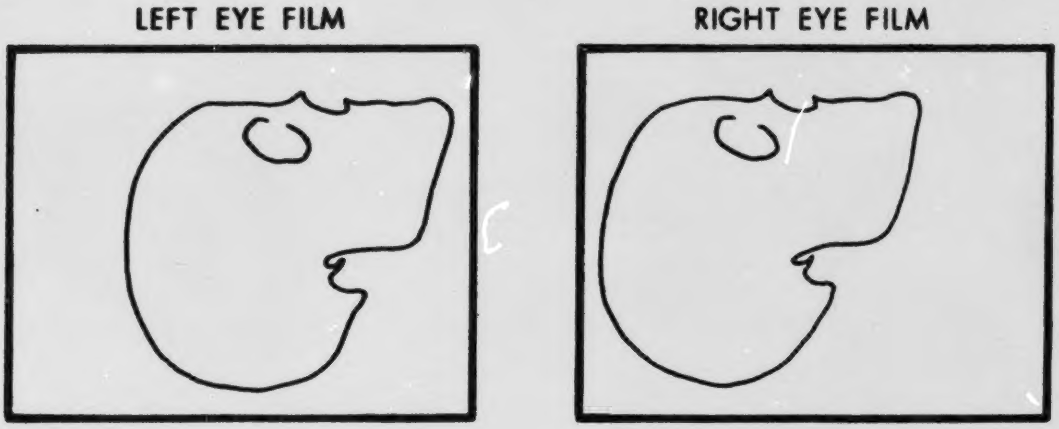
Mirror Stereoscopic Viewing. While many radiologists and technicians view stereoscopic radiographs by crossing their eyes, most stereoscopic viewing is performed by mirror devices. Several types of devices are available, and they all work basically the same. The mirrors are arranged so that your right eye sees the film on your right and your left eye sees the film on your left. Consequently, film placement with respect to right or left is opposite from that of cross-eyed stereoscopy. The orientation of the tube shift axis is the same as with cross-eyed stereoscopy.

Whether you place the films on the viewboxes with the tube sides toward you depends upon the number of mirrors in the device for each eye. Some viewing devices use one mirror for each eye. In this case, place the films so that the tube sides are away from you or against the viewboxes. Other devices that use two mirrors for each eye require the films to be placed with the tube sides toward you.



A PA STEREO PROJECTIONS, LEFT HIP

← TUBE SHIFT →



B LEFT LATERAL STEREO PROJECTIONS

← TUBE SHIFT →

Figure 4-11. Objective 437, exercises 1-2.

Exercises (437):

1. Are the two films in figure 4-11,A, correctly placed for stereoscopic viewing with a double mirror device? If not, why?

2. Are the two films in figure 4-11,B, correctly placed for stereoscopic viewing with a single mirror device? If not, why?

CHAPTER 5

Localization of Foreign Bodies

ALMOST EVERY FOREIGN body, whether a broken needle in the foot or a tiny particle in the eye, must be surgically removed from the patient. Your specific job depends upon the location of the foreign body. You may only be required to perform the radiographs or you may have to determine the exact location of the foreign body.

In this chapter, we will discuss methods for localizing foreign bodies in the extremities, in the trunk, and in the eye.

5-1. Localizing Foreign Bodies in the Extremities

A foreign body in an extremity its usually localized by the *two-view* method.

438. Explain significant factors relating to the two-view method of foreign body localization.

General Procedure. Basically, the two-view method of foreign body localization consists of taking an AP or a PA and lateral projection of the affected part with some sort of marker placed on each film to serve as a reference point. While the procedure seems simple enough, the physician may have difficulty finding and removing the foreign body unless you perform the procedure properly.

Importance of Proper Positioning. As we mentioned, AP or PA and lateral projections should be taken, rather than *any* two projections at right angles to each other. The reason for this is that the physician determines the location of the foreign body and the best route for removing it by comparing the radiographs to visual inspection of the part. The position of the part (during his inspection) and the position of the part when the radiograph is made must be the same. The physician can easily examine the part in the AP, PA, or lateral positions, but he may not be able to duplicate the positions of the radiographs if they are obliques.

The Orientation Marker. The two radiographic projections readily demonstrate the location of the foreign body with respect to the anterior/posterior or medial/lateral surfaces of the part. In order to precisely localize the foreign body proximally/distally, it is usually necessary to include an orientation marker on each radiograph.

Placing the marker on the entrance wound. Some radiologists prefer a small metallic marker such as the letter "X" or "O" taped directly over the entrance wound—if one is visible. Both projections are made with the marker in place. The main problem with this marker placement is that the foreign body may be superimposed over the marker on one projection and, therefore, indistinguishable on the radiograph.

Placing the marker on the film holder. The most common placement of the orientation marker is directly on the film holder in the same transverse plane as the entrance wound. In this case, the marker is usually an arrow, located so that it does not superimpose any tissue, and pointed toward the wound. The arrow is used on both projections.

If an entrance wound is not visible, make a mark on the patient's skin near the suspected location of the foreign body and align an arrow on the film holder as described above.

Exercises (438):

1. What projections should be made to localize a foreign body in the extremities?

2. Is it sufficient to perform any two projections at right angles to each other to localize a foreign body in the extremities? Explain your answer.

3. Why should an orientation marker be included on the radiograph when localizing a foreign body in an extremity?

4. Describe three ways to include an orientation marker on the film when localizing a foreign body in an extremity.

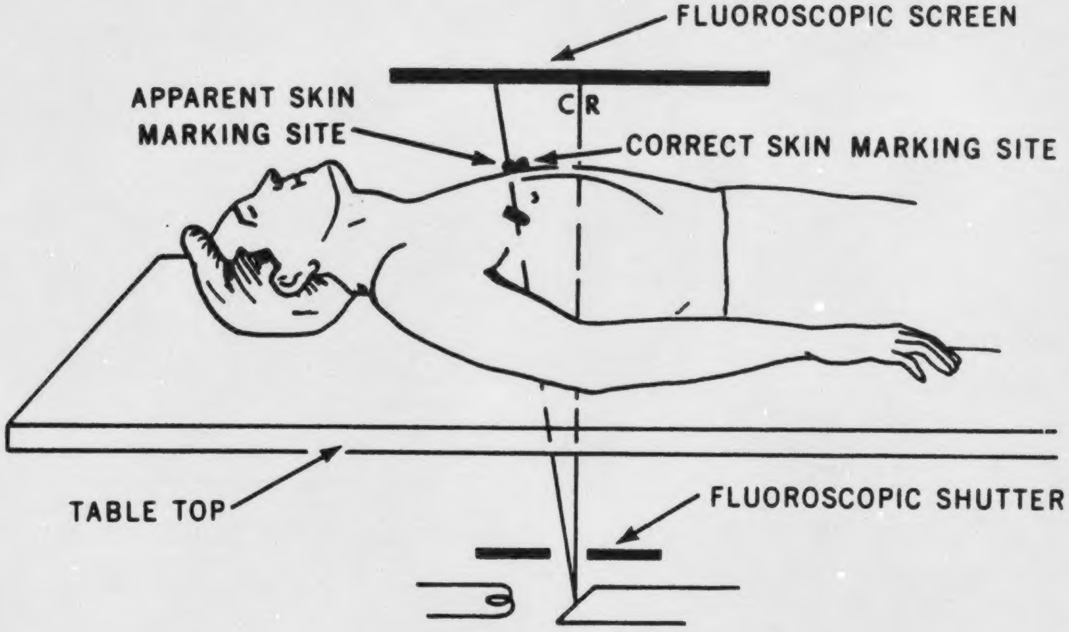


Figure 5-1. Illustration showing how the skin may be incorrectly marked if the CR is not used to localize a foreign body.

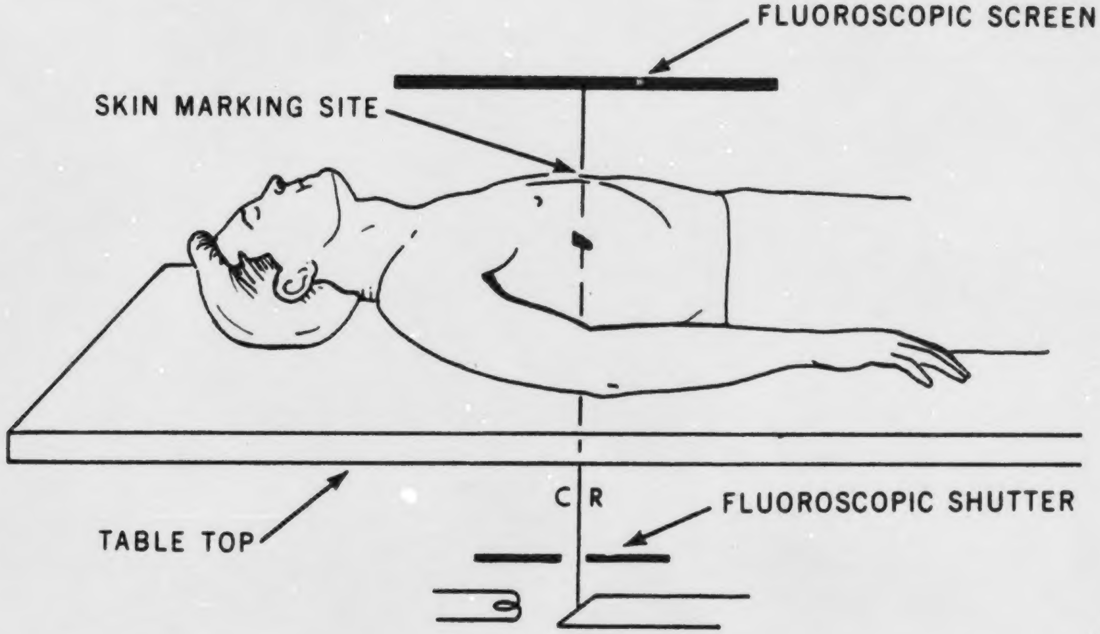


Figure 5-2. Illustration showing the proper CR alignment when locating a foreign body by fluoroscopy.

5-2. Localizing Foreign Bodies in the Trunk

A foreign body in the trunk is usually localized by using the *single triangulation* method. With this method, you determine the depth of the foreign body beneath the surface. We will discuss the procedure for performing the radiograph first and then the procedure for calculating the depth.

439. Given a list of statements about the procedure for performing the radiograph, using the single triangulation method of localizing a foreign body, indicate which are true and which are false.

Radiographic Procedure. Basically, the procedure for determining the depth of the foreign body consists of double exposing the film so that the foreign body appears twice on the radiograph.

Marking the skin. The first step is to locate the foreign body with respect to its medial/lateral, superior/inferior location. Determine this location by fluoroscoping the patient. Place a mark on the patient's skin directly over the foreign body. Your mark tells the surgeon that the foreign body is directly below. If you do not use the CR of the fluoroscopic beam to locate the foreign body, your mark on the skin will not be accurate.

Notice in figure 5-1 that the central portion of the beam is not used to project the foreign body on the film. Therefore, the skin marking site is not correctly indicated. In figure 5-2, the CR is used to project the foreign body, and the skin is correctly marked. (NOTE: In the case of the foreign body shown in figures 5-1 and 5-2, the error causes the mark to lie over the end of the foreign body rather than over the center as it should. If the foreign body is small, the apparent skin marking site in figure 5-1 could miss the foreign body altogether.) The best way to avoid incorrectly marking the skin is to collimate to a small cone field (slightly larger than the foreign body) and center the foreign body inside the X-ray field.

Performing the radiograph. The next step is to perform the radiograph. Center the tube, patient, and film so that the CR is perpendicular to the center of the film, and passes through the skin mark and foreign body. Record the *exact* FFD and the *exact* distance from the patient's skin (mark on skin) to the film. (NOTE: The depth of the foreign body is determined in millimeters. You can either record all measurements in mm or convert them to millimeters later during the calculation.) Make an exposure using half the normal mAs. Shift the tube longitudinally 6 to 8 inches. Record the *exact* amount of tube shift. Make another exposure using the same technique. Process the radiograph.

Exercises (439):

Indicate which of the following statements are true and which are false. If you indicate "false," explain your answer.

T F 1. The only significance of the skin mark is that it tells the surgeon that the foreign body lies directly below.

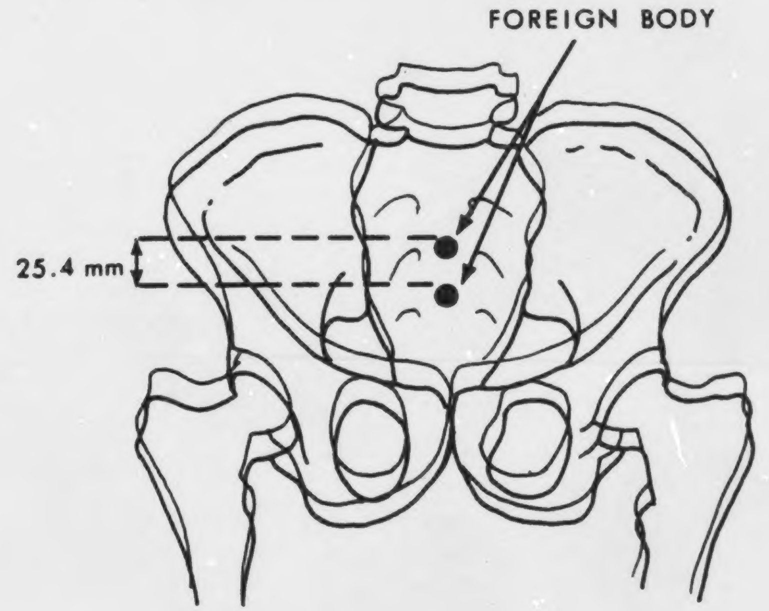


Figure 5-3. One correct way to measure the image shift.

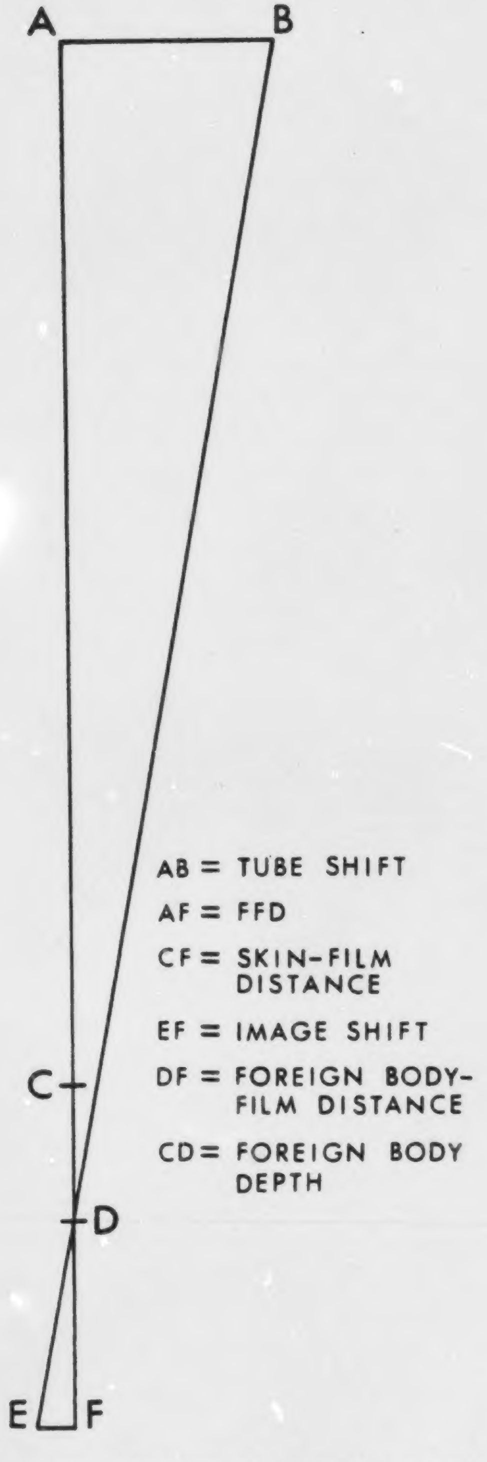


Figure 5-4. Geometrical relationships of tube-skin-foreign body and image.

T F 2. The two images of the foreign body appear medial/lateral to each other on the radiograph.

T F 3. Collimation of the primary beam is not important during the fluoroscopic procedure.

T F 4. Both radiographic exposures are made with the same mAs.

T F 5. A tube shift of 7 inches during radiography is correct.

T F 6. The FFD, skin-film distance, tube shift distance, and tube-skin distance are recorded.

T F 7. Neither foreign body image is projected with the CR.

440. Given drawings of two radiographs, each showing a foreign body and the related radiographic data, calculate the depth of each foreign body.

Calculation Procedure. Now that you have made the radiograph, let's see how to calculate the depth of the foreign body. Your radiograph will show two images of the foreign body due to the tube shift. Measure the distance between any two similar points of the foreign body. In figure 5-3, the distance is 25.4 mm.

Conversion to millimeters. The next step is to convert the following measurements to millimeters—1 inch = 25.4 mm. The measurements are demonstrated geometrically in figure 5-4:

IS— image shift measured on film = 25.4 mm.
FFD— recorded earlier - 40 inches = 1016 mm.
TS— tube shift recorded earlier - 6 inches = 152.4 mm.
SFD— skin-film distance recorded earlier - 10 inches = 254 mm.

Determining the foreign body to film distance. After you convert all measurements to millimeters, find the foreign body to film distance (FBFD) by using the following formula:

$$\text{FBFD} = \frac{\text{IS} \times \text{FFD}}{\text{IS} + \text{TS}}$$

Substituting our figures, we see that

$$\text{FBFD} = \frac{25.4 \times 1016}{25.4 + 152.4}$$

$$= \frac{25806.4}{177.8}$$

$$= 145$$

Determining the depth of the foreign body. Finally, use the following formula to determine the depth of the foreign body (FBD).

FBD = SFD − FBFD
= 254 − 145
= 109 mm

Exercises (440):

Figure 5-5 shows drawings of two different radiographs taken to calculate the depth of two foreign bodies. Using the data supplied below and on each drawing in the figure, calculate the depth of each foreign body.

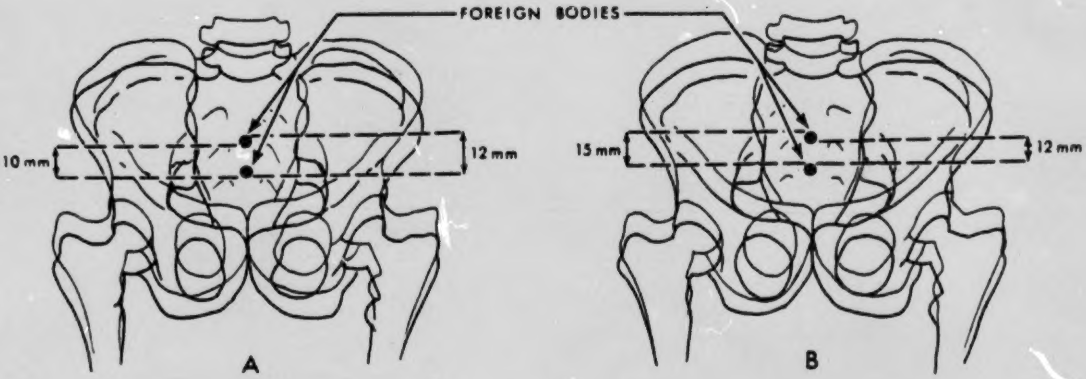


Figure 5-5. Objective 440, exercise 1-2.

1. Drawing A—figure 5-5.
FFD = 36 inches.
TS = 5 inches.
SFD = 12 inches.

2. Drawing B—figure 5-5.
FFD = 38 inches.
TS = 7 inches.
SFD = 8 inches.

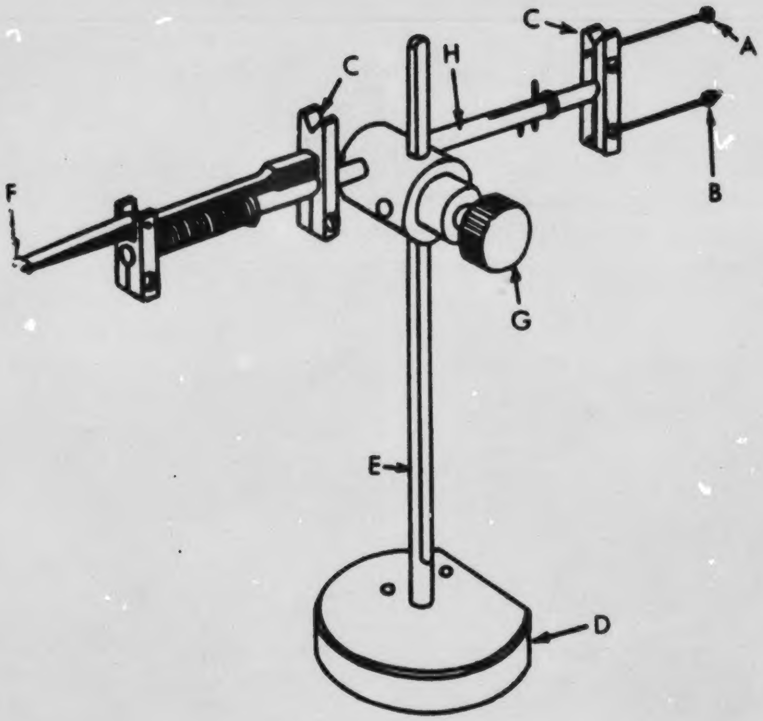


Figure 5-6. Sweet's localizer.

5-3. Localizing Foreign Bodies in the Eye

There are many different methods for localizing foreign bodies within the eye. All of the methods, if performed correctly, are quite accurate. The method you use in your department depends upon the preference of your radiologist.

In this section, we will discuss the *Sweet's* method for determining the exact location of a foreign body in the eye. We begin with a review of the parts of the Sweet's localizer.

441. Given a photograph of a Sweet's localizer, identify key parts by name and by function.

Sweet's Localizer. The Sweet's localizer shown in figure 5-6 is positioned near the patient's affected eye during the two exposures. Let's examine the key parts of the localizer. Refer to figure 5-6 as we discuss the parts.

Base. The heavy metal base (D) supports the entire unit.

Vertical arm. The vertical arm (E) is supportive and allows for adjustment of the horizontal arm.

Horizontal arm. The horizontal arm (H) is supportive and adjusts to properly align the ball.

Ball and cone. The ball (A) and cone (B) are projected onto the radiographs and serve as reference points for localization of the foreign body.

Sighting notches. Two sighting notches (C) help you visually align the ball to the center of the cornea.

Set screw. The set screw (G) allows the horizontal arm to be raised or lowered so that the ball can be positioned correctly in relation to the patient's eye.

Trigger release. The trigger release (F) causes the ball and cone to move back exactly 10 mm from the patient's eye.

Exercises (441):

Figure 5-7 is a photograph of a Sweet's localizer. Each key part is identified by a number. Identify each part by placing the correct number in each space provided in exercises 1-8.

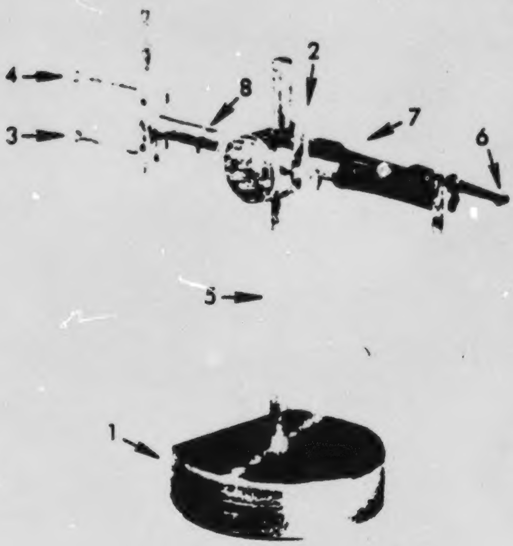


Figure 5-7. Objective 441, exercises 1-13.

____ 1. Set screw.
____ 2. Sighting notch.
____ 3. Ball.
____ 4. Vertical arm.
____ 5. Cone.
____ 6. Horizontal arm.
____ 7. Base.
____ 8. Trigger release.

Identify the functions of parts in figure 5-7 by placing the correct number(s) in each space provided in exercises 9-13, describing functions.

____ 9. Reference point on radiograph.
____ 10. Supportive.
____ 11. Visual aid for ball and cornea alignment.
____ 12. Drops ball and cone back 10 mm from eye.
____ 13. Permits raising or lowering of horizontal arm.

442. Explain key factors involved in the procedure for performing the Sweet's eye localization radiograph.

Performing the Radiographs. For precise location of the foreign body in the eye, the Sweet's method uses two exposures on a single crosswise 8- by 10-inch cassette. Let's examine the procedure.

First exposure. Place the Sweet's headrest on one end of the table. With an 8- by 10-inch cassette in the sliding tray, insert the tray into the headrest tunnel to the first red mark on the tray handle (the mark nearer the cassette). Two red marks on the handle are used to center half of the 8 by 10 film to the crossed lines on the headrest. Instruct the patient to assume the lateral recumbent position with the cornea of the affected eye down and centered over the crossed lines in the center of the headrest. Adjust the patient's head to the *true* lateral position. Secure the head position with headclamps.

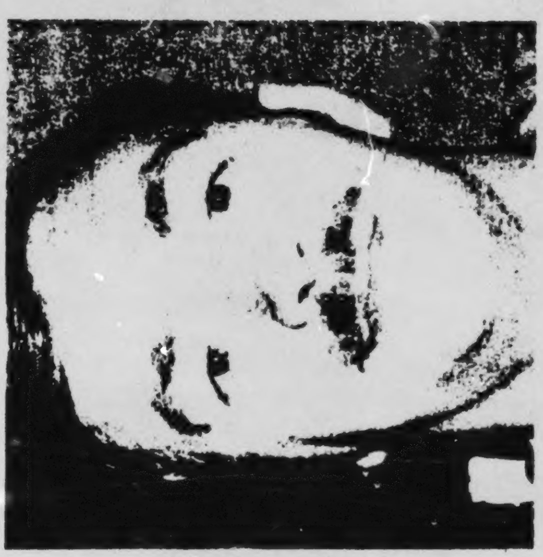


Figure 5-8. True lateral position of the head for Sweet's eye localization.

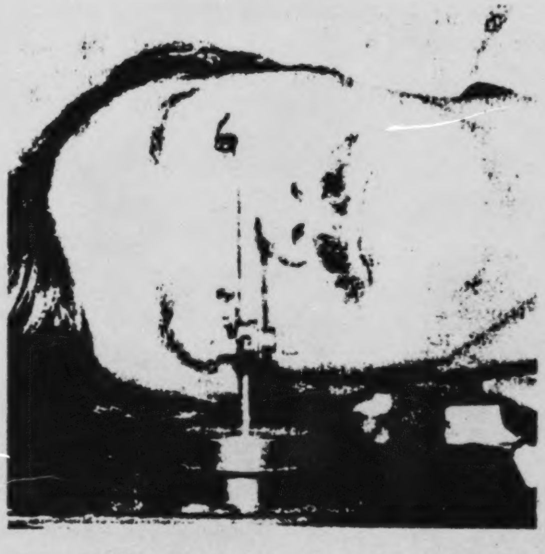


Figure 5-9. Using the sighting notches to align the ball of the Sweet's localizer to the center of the cornea.

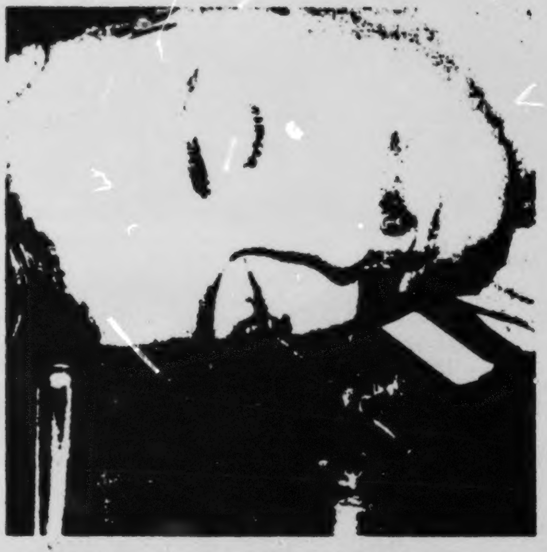


Figure 5-10. Position of the ball of the Sweet's localizer against the patient's eyelid.

Align the CR to a point 10 mm anterior to the most anterior surface of the cornea. See figure 5-8.

Place the localizer on the headrest in front of the patient's eyes with the ball and cone near the patient's lower eye. Have the patient focus his eyes on an object near the wall he is facing or on an object you have taped to the wall. The object should be in the same vertical plane as are the patient's eyes and in the same horizontal plane as the median plane of his head.

Loosen the set screw on the localizer. Adjust the horizontal arm of the localizer and the position of the localizer on the headrest so that the center of the ball is in the same horizontal and vertical planes as the center of the cornea of the eye. Use the sighting notches. See figure 5-9. The center of the cornea is located anterior to the center of the pupil. After alignment, tighten the set screw.

After instructing the patient to close his eyes, slide the localizer forward until the ball touches and slightly depresses the eyelid. The amount of depression should approximately equal the thickness of the eyelid. (See fig. 5-10.) While holding the localizer base with one hand to keep it from moving, depress the trigger release to allow the ball and cone to drop back 10 mm from the cornea. (This distance is preset in the localizer.) Before depressing the trigger release, place your hand against the sighting bracket so that it will cushion the mechanism and allow it to drop back gently and not abruptly. (An abrupt drop might startle the patient.) (See fig. 5-11.) Have the patient open his eyes to look at the preselected object again. Make an exposure.

Second exposure. Angle the X-ray tube 15° to 25° cephalic and direct the CR midway between the ball and cone. Push the cassette tray into the headrest

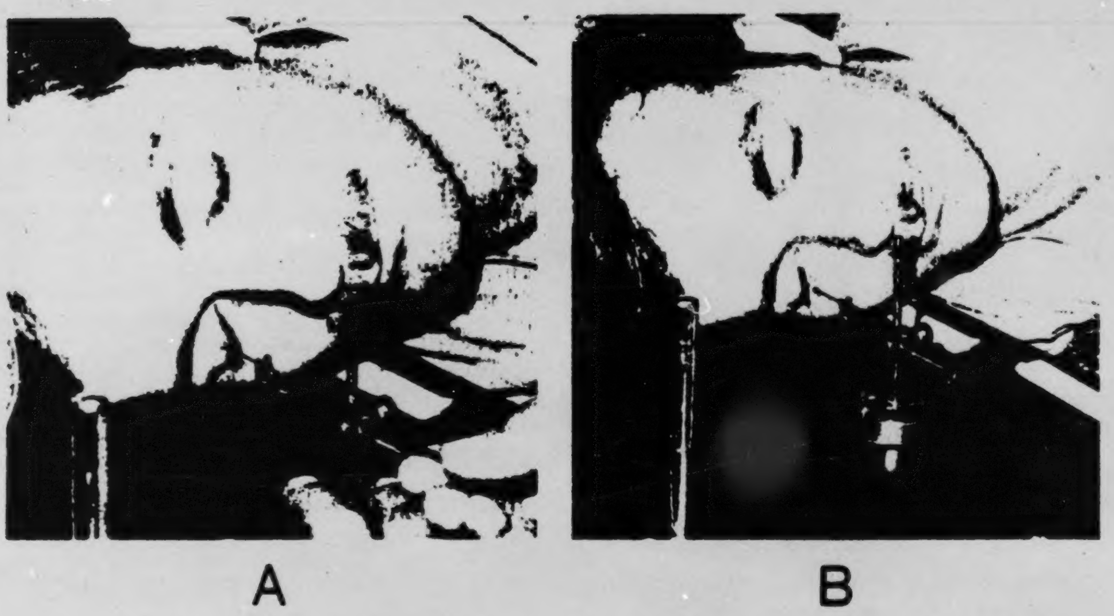


Figure 5-11. Releasing the trigger on the Sweet's localizer. (A) Notice the right thumb is depressing the trigger while the right index finger cushions the release of the mechanism. (B) Position of the ball and cone after release.

tunnel to the second red mark on the tray handle. Make another exposure.

Exercises (442):

Answer the following questions pertaining to the procedure for performing Sweet's eye localization radiograph.

1. How many films are used and how many exposures are made?

2. How is each half of the film centered to the headrest?

3. In what position is the patient's head placed for both exposures?

4. To what specific points is the CR directed for each exposure?

5. What is the relationship between the location of the object on which the patient focuses his eyes and the location of the patient's eyes?

6. What is the relationship between the ball of the localizer and the patient's affected eye just before you slide the localizer toward the patient's eye?

7. How much should the ball depress the eyelid?

8. Do you depress the trigger release before or after the patient opens his eyes?

9. What distance does the ball and cone move when the trigger release is depressed?

10. What precaution should be taken before depressing the trigger release? Why?

11. What tube angle in what direction is used for the second exposure?

443. Answer key questions about factors deserving special attention during the Sweet's eye procedure.

Special Considerations. You and I both know that *some* radiographic examinations are not critical. For example, it would be difficult to tell whether the CR was directed to the fifth, sixth, or seventh thoracic vertebra for a particular PA chest if the cone field were not visible on the film. However, positioning errors must be avoided when performing the Sweet's method of localization. You must provide radiographs which allow the radiologist to determine the *exact* location of the foreign body—this means careful attention to the details of the examination. It is easy to understand the necessity of precise localization of the foreign body if you realize that the tissues of the eye are particularly susceptible to damage. Consequently, if the ophthalmologist knows the precise location of the foreign body, he has a better chance of removing it without additional damage to the eye.

Patient cooperation. When the information on the radiographs is plotted to determine the foreign body's location, it is done so under the assumption that the patient's eye is looking straight ahead—when the ball is aligned to the cornea and when both exposures are made. This position of the eye requires complete cooperation from the patient.

Perhaps the best way to insure his cooperation is to explain the details of the procedure to him. Tell him exactly what you are going to do and in what order. It is rather difficult for the patient to maintain the position of the eye in the first place. It is more difficult if he is apprehensive.

Preparation and speed. As previously mentioned, it is difficult for the patient to maintain the correct position of the eye. Keep in mind that he has a piece of foreign material in his eye and is no doubt uncomfortable and experiencing pain. The quicker you accomplish the examination, the more successful it will be.

Prepare everything in advance. For example, set the technique and decide what tube angle you will use for the second exposure. Once you start the examination, act quickly. It is advisable to use another technician to assist you to reduce the examination time. If you use an assistant, make sure that he knows what he is supposed to do and when to do it.

CR alignment. Correct alignment of the CR is especially important during the Sweet's examination. The ball and cone and their

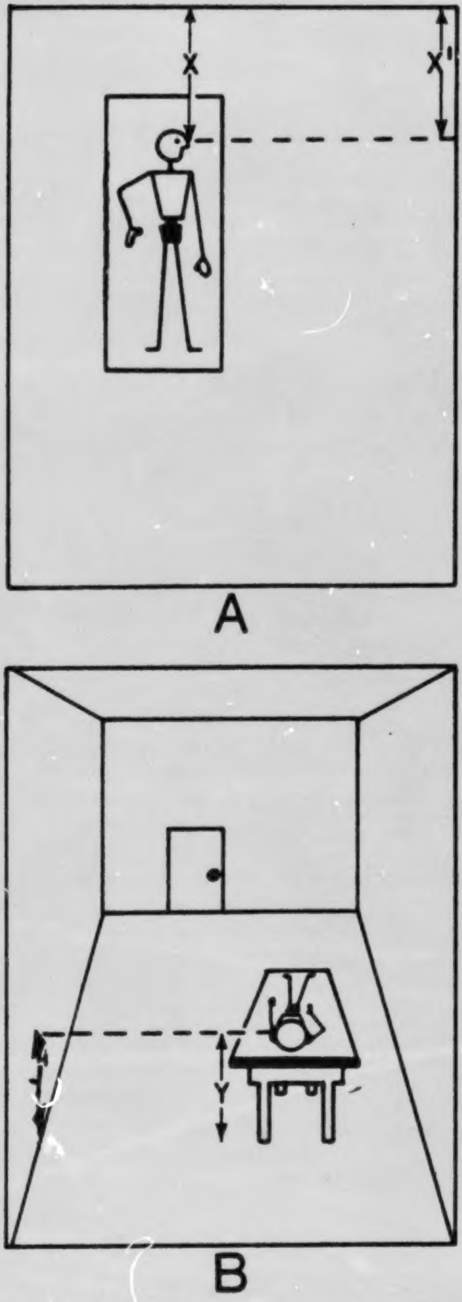


Figure 5-12. Determining the object position on which the patient focuses his eyes.

supporting rods must be exactly superimposed by the first exposure or the film measurements are erroneous. The CR is angled on the second exposure to separate the ball and cone. The exact angle within the specified range is not important as long as the CR is directed between the ball and cone.

Head position. The head must be in the true lateral position or the view of the eye is not correct. Even a small amount of anterior or posterior rotation or superior or inferior longitudinal angulation is sufficient to cause the foreign body to be incorrectly located.

Eye-object alignment. The alignment of the patient's eyes to an object directly in front of him is important. A good way to determine the location of the object is to make some measurements as shown in figure 5-12. In drawing A, the top wall is used as a reference point to determine the location of a vertical plane through the object. Distances X and X' are equal. In detail B, the floor is used as a reference point to determine the location of a horizontal plane through the object. Distances Y and Y' are equal.

Exercises (443):

Answer the following questions about important considerations of the Sweet's foreign body localization method.

1. Why is it important for you to perform the examination without error?

2. What is perhaps the best way to insure the patient's cooperation?

3. Why should you perform the examination quickly?

4. Why is the CR directed perpendicularly through the ball and cone during the first exposure?

5. Why is the CR angled and directed between the ball and cone for the second exposure?

6. Why should the head be positioned in the true lateral position?

7. Explain one method of determining the location for placement of an object on which the patient focuses his eyes.

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Scanography and Arthrography

YOU WILL RECALL that we have referred to magnification of a part several times in this CDC. As a rule, our discussions have been concerned with reducing magnification to a minimum. The first section of this chapter, scanography, is basically more of the same—that is, reducing magnification of a part, although we go about it in a different manner.

The second section deals with arthrography, a procedure that may be classified as a special examination in some departments because of its infrequent accomplishment. We begin our discussion with the purposes of scanography.

6-1. Scanography

Through the years, scanography has been performed by one of two methods: the *slit* or *spot* methods. The slit method involves movement of the tube during exposure. Moving the tube requires either a technician to physically move it along the long axis of the bone or a system of pulleys and cables that does this. Both of these conditions present certain problems not encountered with spot scanography—and since you can produce any type of scanogram using the spot method, we will discuss only the spot method in this CDC.

444. State two specific purposes of scanography.

Purposes of Scanography. A scanogram is performed to determine the length of long bones. It may be performed to determine the numerical length of a long bone such as the tibia, femur, or humerus. An examination to determine the longitudinal dimension provides the radiologist with a radiograph to measure the actual length of the bone. At times, depending on what specific information the orthopedist wants, the radiograph need not show the numerical dimension of the bone. It only has to demonstrate the relative length of one bone as compared with that of the opposite bone. An example is the length of the right femur as compared to that of the left femur.

Exercise (444):

1. What are two specific purposes of scanography?

445. Compare the CR-part-film alignment and part magnification of a conventional radiograph and a scanogram of a long bone.

Principles of Scanography. As we mentioned before, magnification is reduced to a minimum during scanography. Of course, you usually try to keep magnification to a minimum during most radiographic examinations, so reducing magnification is nothing new. However, since we want to produce a radiograph that shows the actual or relative length of a bone, we cannot demonstrate the length simply by "keeping the part-film-distance to a minimum" and "using the longest practical FFD."

If you perform a conventional radiograph of a long bone—the humerus, for example—the relationships between the CR and humerus and between the CR and film are like those shown in figure 61,A. Notice that the length of the image projected on the film is considerably larger than the actual length of the bone. The magnification is obviously caused by the divergence of the primary beam. In general survey radiographs such as this, a certain amount of magnification is acceptable. When you perform a scanogram, however, unless you virtually eliminate the magnification, actual bone measurement is not possible, and relative bone measurements are difficult. If you make two exposures of the long bone diagrammed in figure 6-1,A, and direct the CR perpendicular to each *end* of the bone and the film, as shown in figure 6-1,B, the length of the projected image is the same as the actual bone length. Consequently, to eliminate the magnification resulting from the divergence of the primary beam, you simply use that portion of the

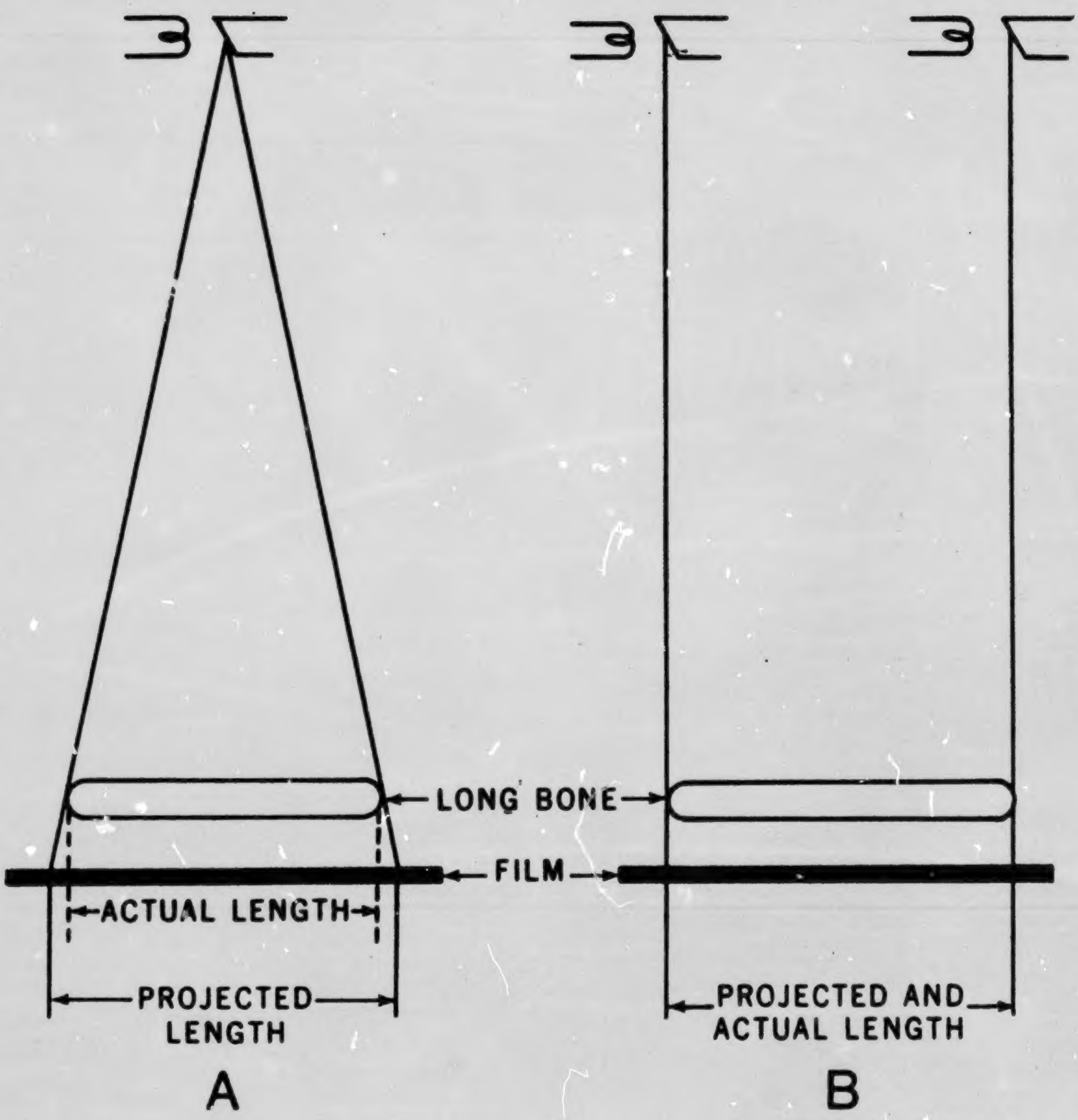

Figure 6-1. Comparison of the magnification of a long bone during conventional radiography and scanography.

primary beam with no divergence, the CR, and make separate exposures of each end of the bone.

Exercises (445):

1. What is the difference, if any, between the CR-part-film alignment during a conventional and a scanographic projection of a long bone?

2. What is the relative difference between the magnification of a long bone radiographed by conventional means and by scanography?

3. Explain the reason(s) for the difference suggested in exercise #2 above.

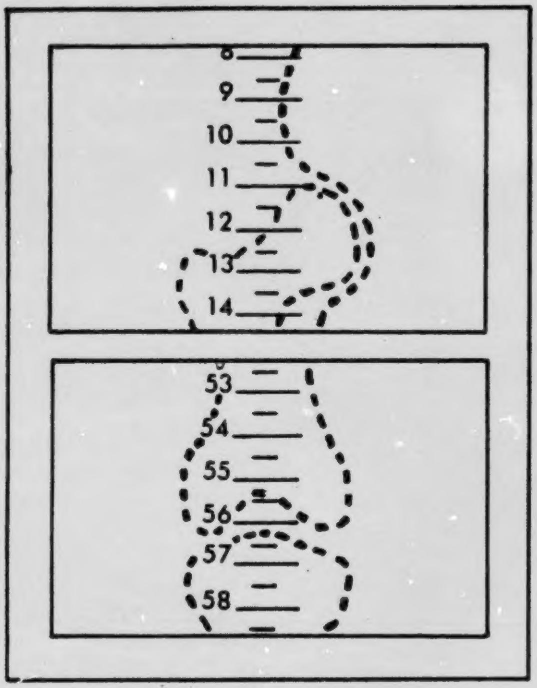

Figure 6-2. Drawing of a scanogram of the femur.

446. Given a list of statements about the procedures for performing scanograms, indicate which are true and which are false.

Scanographic Procedures. There are several ways to produce spot scanograms. The particular method you use depends upon the desires of your radiologist and, usually, of the orthopedist. Also, the procedure depends upon whether the actual or relative length of the bone is desired.

Actual length. There are two ways to perform a scanogram showing the actual numerical length of a bone. One method requires the use of a ruler, scaled in centimeters and constructed so that the scale marks and numerical values are demonstrated on the radiograph. Such a ruler is available commercially and is called a Bell-Thompson ruler. It is 100 cm long and requires an increase of 10 kVp, since it is radiopaque. Let's look at a scanogram of the femur and see how the ruler is used:

a. Suppose a scanogram showing the actual length of the femur is to be performed. Tape the ruler to the table along the centerline. Position the patient for an AP projection (all scanographic projections are AP) so that his femur is directly over the ruler. Be sure that the ruler markings extend to each end of the femur as they should with all bones. Center the top half of film to the superior margin of the femur. Collimate to an X-ray field smaller than half the film so that the entire X-ray field is visible. Align the CR perpendicularly to the center of the top half of the film. Make an exposure. Moving only the Bucky tray and tube, center the bottom half of the film to the knee joint and align the CR perpendicularly to the center of the bottom half of the film. Make another exposure. This radiograph will appear similar to the drawing in figure 6-2. Notice that only two sections of the ruler are seen on the film, but from the radiograph the radiologist can determine the actual length of the femur.

If the length of the entire leg is desired, use the same basic procedure. Project the hip joint on the top third of the film, the knee joint on the middle third, and the ankle joint on the bottom third.

You can also do a scanogram of both legs on the same film, using either three or six exposures. Using three exposures, tape the ruler to the centerline of the table as before. Position the patient for AP projections of both legs on one film. Open the collimator wide enough to include both similar joints on each third of the film and direct the CR to the center of the table. Using six exposures, tape a ruler under each leg and use an X-ray field small enough to project the six joints individually on the film. As is true with all scanograms, do not move the ruler or patient between exposures. Naturally, when six exposures of the legs are made, the tube must be shifted off the grid center for each exposure, requiring consideration and/or compensation for grid cutoff.

b. You can demonstrate the actual length of certain long bones without using a ruler if the entire length of the bone or leg can be projected on a single film without moving the film. With most children you can usually project the femur or tibia on a 14-by 17-inch film. You can also project the entire leg on a 14-by 17-inch film with some very small children. Simply collimate to the joint and make an exposure of each joint, moving only the X-ray tube. No ruler is needed because the bone is not "shortened" by moving the film as is the case with the ruler. The length of the bone is determined by measuring directly with a centimeter ruler.

Relative length. The relative length of long bones (usually the legs) is determined easily without a ruler. Simply follow the procedure for projecting both legs on one film, using three or six exposures. This procedure is usually performed with the patient erect.

Exercises (446):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. Because the Bell-Thompson ruler is

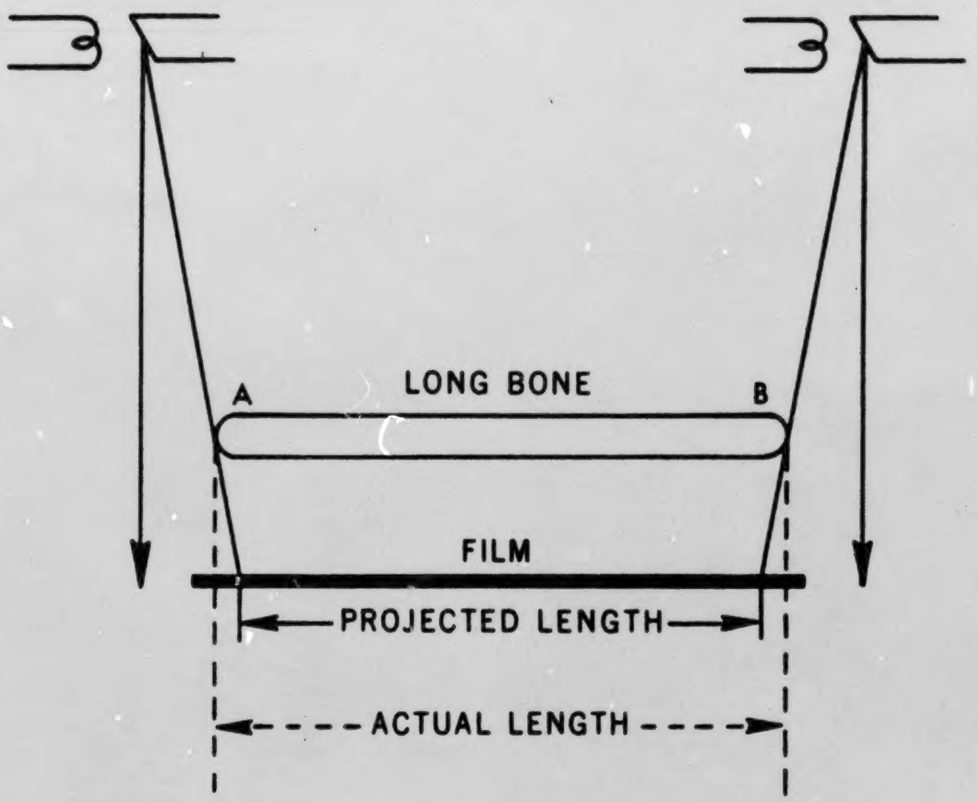

Figure 6-3. Effect of misaligned scanographic CR on measurement of the bone length.

radiolucent, it should be used with a 10 percent increase in kVp.

T F 2. You can perform a scanogram to determine the actual length of a long bone either with or without a Bell-Thompson ruler.

T F 3. A single Bell-Thompson ruler cannot be used to perform an actual length scanogram of the leg on a 14-by 17-inch cassette if the leg measures 110 cm from the proximal femur to the distal tibia.

T F 4. The ruler, patient, film, or tube should not be moved between scanographic exposures.

T F 5. Lateral scanographic projections are frequently performed.

T F 6. If the Bell-Thompson ruler is used for a scanogram, the markings should extend to each end of the bone.

T F 7. A scanogram of both legs can be performed using three or six tube positions.

T F 8. The actual length of an adult femur can be determined on a scanogram using a film shorter than the femur.

T F 9. The number of exposures for a scanogram depends upon the number of major joints present.

T F 10. Two Bell-Thompson rulers are used to perform an actual length scanogram of adult legs on a single 14-by 17-inch film.

T F 11. You can perform an actual length scanogram of an adult femur on a 10-by 12-inch film without a Bell-Thompson ruler.

T F 12. An actual length scanogram of a long bone taken without the presence of a Bell-Thompson ruler will show the two ends of the bone separated by an unexposed area.

T F 13. A Bell-Thompson ruler need not be used for a relative length scanogram.

447. Given descriptions of three scanograms, answer key questions about the CR alignment or magnification of the bones.

Quality Control Considerations. When you

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evaluate scanograms from a quality control point of view, pay special attention to where the CR was directed. Notice in figure 6-3 that we show a CR of a scanogram incorrectly directed to points away from the ends of the bone. The result is that the length of the image is smaller than that of the bone due to the divergence of the primary beam. If the CR were directed to points A and B in the figure, the image would be longer than the bone, for the same reason.

The best way to determine where the CR was directed is to find the centers of each X-ray field on the film. Obviously, you can only locate the CR if the X-ray field is smaller than that portion of the film on which the image is projected. If you cannot see the borders of the X-ray field, you cannot be sure where the CR was directed. Some technicians feel that as long as they mask off the unused portions of the film, the alignment of the CR is not important. Masking is important to reduce film fog due to scattered radiation; however, proper masking in *combination* with the correct CR alignment helps to insure a diagnostic examination.

Exercises (447):

Scanogram A is made of an adult tibia on an 8- by 10-inch film. Both the upper and lower halves of the film show X-ray fields completely visualized (all borders are seen). Both X-ray fields are 4 inches square. The proximal edge of the tibia is located one-half inch from the top border of the upper X-ray field. The distal edge of the tibia is located one-half inch from the bottom border of the lower X-ray field.

Scanogram B is made on an adult femur on a 10- by 12-inch film. Both the upper and lower halves of the film show X-ray fields completely visualized (all borders are seen). Both X-ray fields are 5 inches square. The proximal edge femur is located $2^1/_2$ inches from the top border and $2^1/_2$ inches from the bottom border of the upper X-ray field. The distal edge of the femur is located in the same relative location in the lower X-ray field.

Scanogram C is made of an adult femur on a 10- by 12-inch film. Only three borders of the X-ray field (which measures 7 inches across) on the upper half of the film are seen. The upper border is missing from the film. The proximal edge of the femur is located 4 inches from the center of the film. The lower X-ray field is completely visualized and measures 4 inches high by 7 inches across. The distal edge of the femur is located 2 inches from the bottom border of the X-ray field.

On the basis of the descriptions of scanograms A, B, and C above, answer the following questions concerning the CR alignment or projected length of the bone.

1. Which scanogram(s), if any, was (were) taken with the correct CR alignment?

2. Which scanogram(s), if any, projects (project) an image of the bone that is shorter than its actual length?

3. Which scanogram(s), if any, projects (project) an image of the bone that is longer than its actual length?

4. Briefly discuss the CR alignment for each X-ray field on scanogram C.

6-2. Arthrography

Arthrography, as the name implies, is radiographic examination of the soft tissue structures inside a joint space. The procedures for performing an arthrogram vary considerably from place to place. Consequently, some of the information presented here is general in nature. Arthrograms are performed of several joints, including the ankle, knee, hip, elbow, and shoulder. Most commonly, arthrography is performed of the knee; therefore, our discussion in this section is limited to the knee. We begin with a review of the anatomy demonstrated by a knee arthrogram. After that, we will discuss the preparation and injection procedures and, finally, radiographic procedures.

448. Given a list of structures located inside the knee joint, demonstrated by an arthrogram, match each with statements about their location and function in another list.

Anatomical Considerations of the Knee. As you know, bony structures about the knee are normally well demonstrated on conventional knee radiographs. Certain soft tissue structures, however, are only visualized on an arthrogram. Let's discuss the soft tissue structures.

Menisci. The menisci are two cartilaginous pads, each of which is located between the medial or lateral femoral condyle and the medial or lateral superior articular surface of the tibia. Depending on their relative locations, the menisci are referred to as the medial or lateral meniscus. The menisci act as shock absorbers in the knee joint.

Collateral ligaments. There are two collateral

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ligaments. The fibular collateral runs superoinferiorly along the fibular side of the knee. It attaches superiorly to the lateral femoral condyle and inferiorly to the head of the fibula. The tibial collateral ligament also runs superoinferiorly, but along the tibial side of the knee. It attaches superiorly to the medial femoral condyle and to the proximal, medial surface of the tibia inferiorly. Both collateral ligaments prevent medial or lateral movement of the joint.

Cruciate ligaments. The cruciate ligaments, anterior and posterior, provide anterior or posterior stability of the knee joint. The anterior cruciate attaches anteriorly to the intercondylar eminence of the tibia, runs posteriorly and laterally through the femoral intercondylar fossa, and attaches to the posterior part of the medial surface of the lateral femoral condyle. The posterior cruciate ligament attaches to the posterior intercondylar fossa of the tibia, runs anteriorly and medially through the femoral intercondylar fossa, and attaches to the anterior part of the medial surface of the medial femoral condyle.

Exercises (448):

Match the knee joint structures in column B with the correct statements describing the location and function of the structures in column A by placing the letter of the column B structure in the space provided in column A. Each column B letter may be used once, or more than once.

Column A

Location

___ 1. Extends from head of fibula to lateral femoral condyle.

___ 2. Runs through the femoral intercondylar fossa.

___ 3. Extends superoinferiorly along the medial side of the knee.

___ 4. Located between the medial femoral condyle and medial, superior articular surface of tibia.

___ 5. Attaches to intercondylar eminence of tibia.

___ 6. Attaches to posterior intercondylar fossa of tibia.

Function

___ 7. Maintains anterior or posterior stability.

___ 8. Prevents medial or lateral movement of the knee joint.

Function

___ 9. Acts as a shock absorber.

Column B

a. Meniscus.
b. Collateral ligament.
c. Cruciate ligament.

449. Answer key questions about patient preparation and injection procedures involved during an arthrogram of the knee.

Patient Preparation and Injection. The patient preparation and injection procedures involved during an arthrogram of the knee vary from one radiologist to another. Therefore, we will provide you with some general guidelines to help you assist most radiologists, no matter what their preferences are.

Patient preparation. Shave the lateral surface of the patient's knee joint and clean and prepare the skin, as directed by your radiologist. Surgical soap, alcohol, zephiran chloride, tincture of iodine, or a combination of these items may be used. Then drape the area with sterile towels or sheets.

Injection procedures. The radiologist usually injects a local anesthetic to deaden the injection site. He then injects the contrast medium into the joint space. A water soluble positive contrast medium is used. If a pneumoarthrogram is to be performed, a[illegible] oxygen, or carbon dioxide may be injected. If a positive medium is used, he will probably inject about 10 to 15 cc of the solution. If joint effusion is present, more contrast medium is usually injected (up to twice the normal amount); otherwise, dilution will prevent a good study from being performed. The radiologist also normally attempts to aspirate as much fluid as possible when joint effusion is present to keep dilution of the medium to a minimum. The amount of negative medium injected may be 20 cc or more if a pneumoarthrogram or double contrast study is performed.

After covering the injection site with sterile gauze, the radiologist usually massages the knee to distribute the contrast medium throughout the joint space. He may also allow the patient to stand and walk to provide distribution of the medium. Some radiologists also wrap the knee tightly with an ace bandage to force the contrast medium out of the quadriceps pouch onto the surfaces of the menisci. When an ace bandage is used, it should be removed before the lateral radiographs of the knee are made in order to permit visualization of the quadriceps pouch.

Exercises (449):

1. Briefly explain how the knee is prepared for injection during an arthrogram.

2. What type of positive contrast media is injected into the knee joint?

3. a. How many centimeters of positive contrast medium would you normally need for an arthrogram? b. How many centimeters would you need if joint effusion is present?

4. What type(s) of negative contrast medium may be injected into the knee joint?

5. Why does the radiologist aspirate the fluid when joint effusion is present?

6. Name three ways in which the contrast medium may be distributed throughout the knee joint after injection.

7. If the knee is wrapped in an ace bandage, when should it be removed? Why?

450. Given a list of statements about the procedures for performing the radiographs during an arthrogram of the knee, indicate which are true and which are false.

Radiographic Considerations. Several different projections and types of radiographs are performed of the knee during an arthrogram. They vary from radiologist to radiologist. Tomograms, stereoscopic radiographs, as well as standard AP, PA, lateral, and oblique radiographs are accomplished. Obliques may be performed with various degrees of rotation—for example, 30, 45, 60, and 75. Usually, the CR is angled 3° caudad for the AP projections (including posterior obliques) and 6° cephalic for the PA projections (including anterior obliques) to open the joint space. If a pneumoarthrogram or double contrast study is performed, some or all of the projections are usually made with a horizontal CR to take advantage of the rising air.

Speed is essential. The contrast medium injected into the joint capsule is eventually absorbed. Absorption begins within a short time after introduction, and the entire injection can disappear from the joint capsule within 30 minutes. It is obvious that you should work quickly to perform the radiographs before this happens. You must also make sure that the positions, exposure factors, etc., are correct the first time since you may not have enough time to repeat the radiographs. If numerous radiographs are to be taken with various positions, it may be advisable to use an assistant to reduce the examination time.

Marking the joint space. To properly demonstrate the necessary structures, it is important that you direct the CR through the joint space when performing the radiographs. Since some sort of bandage is usually applied to the knee after the injection, it is difficult for you to determine the exact location of the joint. It is usually best to have the radiologist mark the joint space under fluoroscopy after the bandage is applied. If various projections are to be made, a line drawn around the circumference of the knee is helpful.

Exercises (450):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. The projections and types of radiographs vary from radiologist to radiologist.

T F 2. The PA and AP projections are usually taken with a vertical CR to take advantage of the rising air.

T F 3. Standard 45° obliques are always made.

T F 4. Speed is important to prevent undue patient discomfort.

T F 5. Perhaps you should use an assistant if many radiographs are to be made.

T F 6. The CR must be directed through the joint space.

T F 7. You can estimate the exact location of the joint space if the knee is wrapped in a bandage.

CHAPTER 7

Bedside and Surgical Radiography

IN VARIOUS PARTS of this CDC, we have discussed safety for obvious reasons. We even devoted an entire chapter to the topic in Volume 1. In addition, you will find that we will refer to this important subject again in some of the discussions that follow

Perhaps in no other phase of radiology is safety so important as during bedside and surgical radiography. These examinations bring together most of the safety hazards with which you must contend—hazards which present such dangerous conditions as explosion, fire, electrical shock, overexposure to radiation, and contamination. Due to these conditions, this chapter will deal mainly with the safety hazards of bedside and surgical examinations. We will also briefly discuss the types of mobile units and some general radiographic considerations. We begin with the three types of mobile units.

7-1. Mobile X-Ray Units

Many different brands of mobile X-ray units are on the market today, and several of them can be found at hospitals throughout the Air Force. In this section, we will not discuss specific operational instructions for mobile units since it would be impractical to study all of the different units. Instead, we will present a general discussion of mobile units, the importance of grounding your unit, and the use of mobile units in an explosive atmosphere. We begin our discussion with the three types of mobile X-ray units.

451. Given the three types of mobile X-ray units in one list, match each with an appropriate descriptive statement or phrase in another list.

Types of Mobile X-Ray Units. Three types of mobile X-ray units are in use at present. They are: (1) the type found in most Air Force hospitals, which we will call standard, (2) capacitor-discharge, and (3) battery-powered.

Standard. A standard mobile unit uses direct power line current during the exposure, as opposed to a capacitor-discharge or battery-powered unit, which in effect uses "stored" current. Some of these units operate only on 110-volt circuits, some operate on 110- or 220-volt circuits, while others operate only on 220-volt circuits.

Other than the power supply, the most significant difference between the standard units is in the output, which covers a wide range. Maximums of 50 mA and less than 100 kVp are generally considered too low for use in a hospital that performs frequent portable examinations. A unit capable of delivering 110 mA and 100 or more kVp is quite necessary in such a hospital.

Capacitor-discharge. A capacitor-discharge mobile unit normally uses a 110-volt power supply. It differs from the units mentioned previously in that a charge period, usually of a few seconds, must precede each exposure. During these few seconds, a charge of electrical current builds up in the machine. A ready or charge light usually indicates when the charge is completed and, therefore, indicates that the unit is ready for exposure.

Since the capacitor-discharge unit in effect "stores" an electrical charge, it offers additional machine output when compared to another similar unit operating on a 110-volt circuit but without capacitor-discharge design.

Battery-powered. A battery-powered mobile unit receives its power supply from nickel-cadmium battery cells in the unit; therefore, the unit is cordless. Typically, when the cells are fully charged, they can deliver electrical charges sufficient to produce exposures totaling 10,000 mAs at 110 kVp. Recharging is accomplished simply through a 110-volt outlet. The recharging period depends upon the amount of discharge, but it is usually less than 8 hours.

The cordless feature of a battery-powered unit is obviously a significant advantage. You are not limited to using the unit only where a power outlet is available. The natural bother accompanying the use of a cord is also eliminated. In addition, the machine output is not affected by variances in the line voltage or a significant voltage drop when a long power cord is used.

Another advantage of a battery-powered unit is that the waveform across the X-ray tube is similar to that of a three-phase, 12-pulse, X-ray generator in that it is near constant. Thus, the effective capacity of the unit is higher than the stated capacity, perhaps by as much as 50 percent.

Exercises (451):

Match the type of mobile X-ray unit in column B with the appropriate phrase or statement in column A by placing the letter of the column B unit in the space provided in column A. Each column B item may be used once or more than once. In addition, more than one column B item may match a single column A entry.

Column A	*Column B*
___ 1. Effective capacity exceeds stated capacity.	a. Standard.
___ 2. Near constant wave form.	b. Capacitor-discharge.
___ 3. Must be charged before each exposure.	c. Battery-powered.
___ 4. Found in most Air Force hospitals.	
___ 5. Usually operates on 110-volt power supply.	
___ 6. Operates on 110-volt or 220-volt circuit.	
___ 7. Uses stored power.	
___ 8. A single charge permits many exposures.	
___ 9. Can be used where a power outlet is not accessible.	
___ 10. Output covers a wide range.	
___ 11. Recharge from a 110-volt line.	
___ 12. Uses direct power line current.	
___ 13. Eliminates line voltage variations.	

452. List some specific conditions that may exist during a mobile, bedside radiographic examination which could cause electrical shock to you and your patient, and specify two measures that will help to prevent this.

Grounding of Mobile Units. You will recall that we discussed grounding of electrical equipment in Chapter 6 of Volume 1. We discussed some general aspects of grounding as well as specific circumstances involving angiographic and darkroom equipment. Let us now look at some aspects of grounding as it applies to mobile X-ray units.

There is danger of an electrical shock to both you and your patient if your mobile unit is not properly grounded. Let's discuss a typical situation and see why a properly grounded unit is necessary. Suppose that you are performing a bedside radiograph. You have the mobile unit positioned so that the unit itself is in contact with the patient's bed—not an uncommon occurrence. There is a defect in the wiring in your unit so that the machine housing is not isolated from the circuitry. Of course, you are in danger of receiving an electrical shock because you naturally come in contact with the machine. But what about the patient? Is he in danger also?

Suppose that the patient's hospital bed is electrically operated and that it contains a wiring defect similar to that of your machine and is properly grounded. Now let's establish one more condition—the patient is in contact one way or another with the metal framework of the bed. Now you can see that the patient is situated in an electrical circuit from your machine to ground. You can also see that, under the conditions described above, your patient is in extreme danger of receiving an electrical shock.

We realize that the situation described above involves a lot of "ifs" and the chances of its occurring are not great. But when you consider the possible results—a seriously ill patient to whom a minor electrical shock could be fatal—you cannot be too careful about preventing such a situation.

In Chapter 6 of Volume 1 we discussed ways to insure proper grounding to an electrical appliance. Since those procedures apply to your portable unit, we will not repeat them here. We would, however, like to make one final point about performing a bedside radiograph. If at all possible, do not connect the patient into a potential electrical circuit by establishing a connection between your machine and his bed.

Exercises (452):

1. On the basis of information presented in the text, list in any order the specific conditions that may be present during a mobile, bedside, radiographic examination which could subject you and your patient to electrical shock.

2. State two ways you can help to prevent you or your patient from receiving electrical shock as a result of the conditions given in the above exercise.

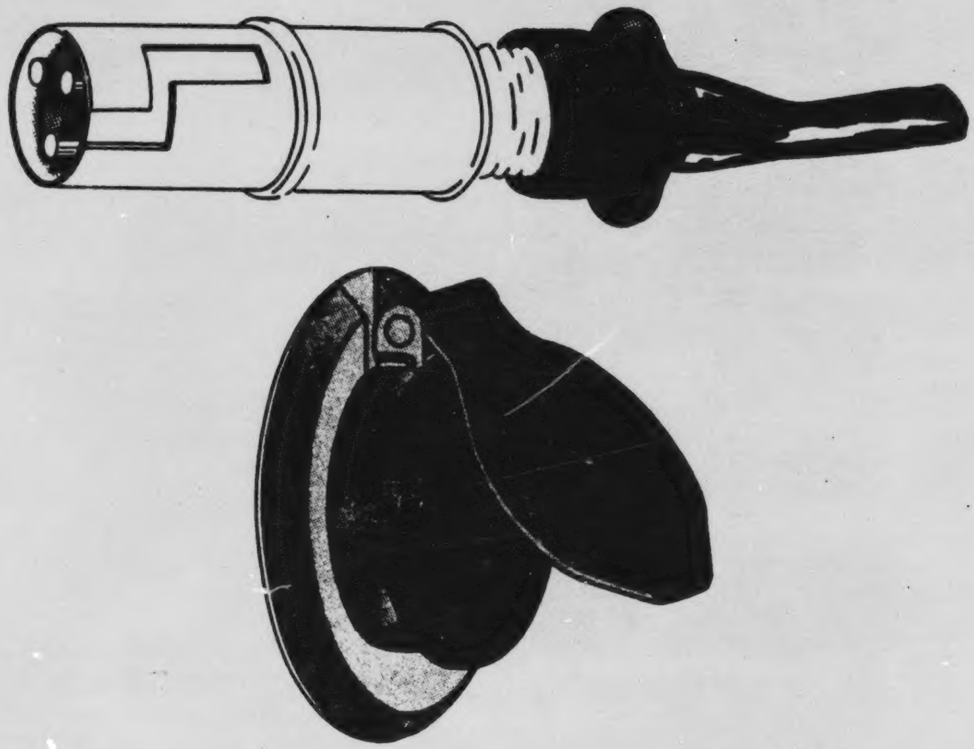

Figure 7-1. Explosionproof plug and its receptacle.

453. Answer key questions about the conditions that constitute an explosive atmosphere and about the use of a mobile X-ray unit in such an atmosphere.

Use of a Mobile Unit in an Explosive Atmosphere. It is extremely dangerous to use a mobile X-ray unit in the operating room if an explosive gas is being used and the unit is not explosionproof. Is your mobile unit explosionproof? Are explosive gases used in the operating rooms in your hospital? If you cannot answer either of these questions, this portion of this chapter should interest you. Let's begin by discussing an explosive atmosphere.

Explosive atmosphere. Certain agents (gasses) used during surgery are highly explosive—meaning simply that they may explode if exposed to a spark or flame. Cyclopropane is an explosive agent. Ether is another. Both of these agents are used in some Air Force hospitals. Both agents are used as a general anesthetic. In addition, ether is sometimes used to "prep" the patient's skin before surgery. Consequently, even though ether may not be used as a general anesthetic, it may still be present in the operating room. An explosive atmosphere is considered to be a room or an area in which an explosive agent is being used, and for a short time after use is discontinued.

Explosionproof unit. An explosionproof mobile unit is a mobile unit that has been manufactured to reduce the possibility of sparking, arcing, or any other occurrence in the machine that could cause an explosion. *All mobile units are not explosionproof.* If you are not sure whether your unit is, contact the manufacturer or a representative and find out.

A unit that is not explosionproof *must not* be used in an explosive atmosphere, for obvious reasons. If your unit is not explosionproof and radiographs are required during surgery, you should contact the anesthetist or anesthesiologist and be sure that he knows about the machine.

Changing of explosive conditions. At times, the person administering the anesthetic may have reason to change agents during the operation. Consequently, even though the operation begins under a nonexplosive agent, an explosive atmosphere may exist later in the operation. You can see how this condition could change your role in using a unit that is not explosionproof. Also, at times the operation may begin under an explosive agent and it may be necessary to change to a nonexplosive agent. In fact, this change is sometimes made for the purpose of permitting

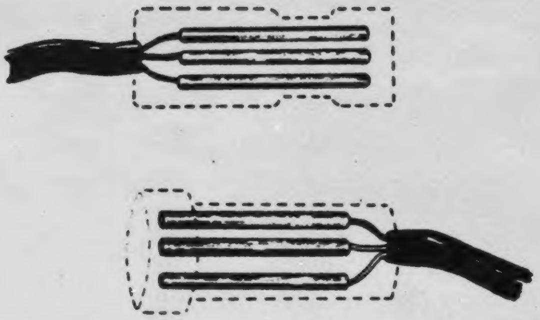

Figure 7-2. Internal construction of the explosionproof plug and its receptacle.

radiographs to be performed. When this is the case, you must wait until the room is sufficiently clear of the agent before performing the radiographs. The anesthetist or anesthesiologist informs you when conditions are safe. The waiting period is normally about 15 minutes after use of the explosive agent is discontinued. A "breath test" is sometimes performed by the anesthetist or anesthesiologist to determine whether or not the atmosphere is safe after use of an explosive agent is discontinued.

Warning statement. AFM 161-38, *Diagnostic X-Ray, Therapeutic X-Ray and Gamma-Beam Protection for Energies Up to 10 Million Electron Volts,* states the following: "The control panel of all diagnostic and therapeutic X-ray units which do not meet the minimum safe construction standards for use in an explosive gas atmosphere as established by the NFPA (National Fire Protection Association) and have UL (Underwriters' Laboratories, Inc.) approval shall bear a legible warning statement." The statement is as follows:

> WARNING: This X-ray unit shall not be used in the presence of explosive gases.

The manual goes on to say that the statement shall be on pressure-sensitive paper approximately $3\frac{1}{2}$ inches wide and 1 inch high, with letters $\frac{1}{3}$ inch or more high. Also, the manual stipulates that the statement shall be located so that it is readily visible to the operator when the X-ray unit is being energized.

Explosionproof plug. Whether or not your mobile unit is explosionproof, you must have an explosionproof plug on the power cord if you use your machine in the operating room. The plug is usually located on one end of a short extension cord. The receptacle for the plug is located 4 to 5 feet above floor level because the greatest concentration of the agent is near the floor.

Both the explosionproof plug and receptacle (see fig. 7-1 and 7-2) are designed so that the electrical connections are enclosed to prevent open sparks. Arcing is most likely to occur at any connection when a plug is inserted into a receptacle. Therefore, connect the extension cord containing the explosionproof plug to the main power cord before inserting the plug into the wall receptacle.

Exercises (453):

1. What is meant by an explosive agent?

2. What are two commonly used explosive agents?

3. Which of the two agents indicated in exercise 2 above is sometimes used to prepare the patient's skin before surgery?

4. Briefly describe an explosive atmosphere.

5. What is an explosionproof mobile X-ray unit?

6. If a surgical procedure begins with an explosive agent, in what situation might the agent be changed to a nonexplosive agent?

7. If an explosive agent is used to begin an operation, and the anesthetic is changed to a nonexplosive agent during the operation, how long must you wait before you can perform a radiographic examination with a mobile unit that is not explosionproof?

8. The minimum safe construction standards of what two national organizations must be met before your mobile X-ray unit is considered explosionproof?

9. If your mobile X-ray unit is not explosionproof, what warning statement should be placed on it?

10. Where should you place the warning statement indicated in exercise 9?

11. What type and what size paper should you use, and what minimum height should you make the letters for the warning statement indicated in exercise 9 above?

12. When should you have an explosionproof plug on the end of your mobile unit power cord?

13. Why is the explosionproof receptacle located 4 to 5 feet above the floor?

14. How do the explosionproof plug and receptacle prevent open sparks?

15. Why should you plug the extension cord containing the explosionproof plug to the main power cord of your mobile unit before plugging the explosionproof plug into the wall receptacle?

7-2. Bedside Radiography

You no doubt have performed many bedside examinations, so you should know by now that you usually have to draw upon your knowledge and experience with the use of grids, film holders, exposure factors, etc., to produce good bedside radiographs. Consequently, we will not discuss those general aspects of bedside radiography. Instead, we will concentrate our study on a few areas that we believe are generally overlooked by many technicians—areas that include minimum source to skin distance, protective apron requirements, and radiography of a patient receiving oxygen therapy and radiography of a cardiac patient.

454. Specify the minimum SSD you should use when accomplishing a mobile radiograph and the minimum lead equivalent of a protective apron worn when performing this radiograph.

SSD and Protective Apron Requirements. While these requirements are included under the heading of bedside radiography, they apply to all mobile radiography. At times when you perform mobile radiographs, it is not possible to achieve your normal FFD. These situations are brought about by several conditions beyond your control, such as the presence of casts, traction devices, and other patient care apparatus. In these circumstances, you may reduce the FFD to that necessary, as long as the SSD (source to skin distance) is not less than 12 inches. The SSD is, of course, the distance from the focal spot to the patient's skin. This minimum SSD is required by AFM 161-38. This manual also requires you to wear a protective apron of at least 0.25 mm lead equivalent.

Exercises (454):

1. What is the minimum SSD that you should use when accomplishing a mobile radiograph?

2. What should be the minimum lead equivalent of a protective apron worn when performing a mobile radiograph?

455. Supply key words in a series of statements about the performance of radiographs on a patient receiving oxygen therapy.

Radiographing a Patient Receiving Oxygen Therapy. While oxygen itself is not combustible, it supports combustion to the extent that pure oxygen can cause a flash fire if a source of ignition is present. For this reason, you must take special precautions when performing radiographic examinations on a patient receiving oxygen therapy.

In *most* cases, the oxygen can and should be turned off for a short time while you are performing the examination. Of course, *you* do not remove the oxygen supply or restart it—this is done by a nurse or other responsible ward personnel. When the patient's condition permits, the oxygen should be turned off during the examination.

If the oxygen is to be turned off and the oxygen tent removed for the examination, be sure to make all the necessary preparations in advance. Preparations such as setting the control panel, positioning the tube and film, and instructing the patient can be performed in advance so that the patient can be returned to oxygen therapy as quickly as possible. You should also work quickly.

If the patient's condition is so critical that the oxygen cannot be turned off at all, and if the examination to be performed is a chest film—which it usually is—the oxygen tent can be draped only around the patient's head, leaving the chest area free.

Exercises (455):

Fill in each blank in the statements below with one or two appropriate words.

1. Oxygen supports ________________.
2. Pure oxygen can cause a __________ ______ if a source of ignition is present.
3. Usually when you are radiographing a patient receiving oxygen therapy, the oxygen supply can and should be ____________________.
4. In the situation indicated above, you do not ________ or ________ the oxygen supply.
5. It is permissible to radiograph a patient while oxygen therapy is being administered only when his ________ prevents removal of the oxygen.
6. Preparing ________ ________ and working ________ can reduce the time a patient is deprived of pure oxygen.
7. If the oxygen cannot be turned off, it is possible to drape the oxygen ________ around the ________ ________ to perform a chest radiograph.

456. Given a list of four bedside chest projections of a cardiac patient, match each with an appropriate descriptive statement given in another list.

Radiographing a Cardiac Patient. Numerous bedside radiographs are made of a cardiac patient whose condition is such that merely moving him to and from a stretcher may jeopardize his recovery. There are at least four ways to accomplish a chest film on this patient. The procedure you use generally depends upon the amount of movement the patient is allowed or that he can tolerate.

Erect PA, 72-inch chest. When performing a bedside chest radiograph on a cardiac patient, your first thought should be directed toward a PA chest taken at a 72-inch FFD with the patient erect. This radiograph, of course, can be as diagnostic from a positional point of view as a routine PA chest performed in the radiology department under ideal conditions.

The procedure for performing this chest radiograph is simple: the patient sits on the side of the bed, holding the vertical cassette in front of his chest. Use a horizontal CR.

Before performing this procedure, make sure by checking with the nurse or physician that it is permissible for the patient to assume this position.

Erect or semierect AP chest. If the patient cannot assume the position described above, you should consider performing an AP chest with the head end of the hospital bed elevated. Elevate the head of the bed to bring the patient to a sitting position. Then place the film behind the patient and direct a horizontal CR from a distance of 72 inches to the vertical film.

At times it may not be possible, due to the patient's condition, to elevate the bed to bring the patient's chest to the erect position, but it may be permissible to elevate it, say, 45°. Although this projection is not as good as the erect AP, this AP projection provides a semierect radiograph and is better than using the supine position. You may not be able to use a 72-inch FFD because the CR must be angled down from horizontal so that it is perpendicular to the tilted film.

Supine AP chest. If it is not possible to position the patient for any of the projections described above, then perform a supine AP chest. Simply slide a cassette under the patient's back and use a vertical CR. Lower the hospital bed to provide the greatest FFD possible (which will be considerably less than 72 inches) so that magnification is kept to a minimum. This projection requires the least patient movement.

Exercises (456):

Match the bedside chest projection of a cardiac patient in column B with the correct statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, more than one column B item may match a single column A entry.

Column A	*Column B*
____ 1. Lower the patient's bed to reduce magnification.	a. PA, erect.
____ 2. Patient holds the cassette.	b. AP, erect.
____ 3. Its use depends upon the patient's condition.	c. AP, semierect.
____ 4. X-ray film is vertical.	d. AP, supine.
____ 5. CR is neither horizontal nor vertical.	
____ 6. Provides best radiograph.	
____ 7. Performed when patient's condition precludes the other three projections.	
____ 8. Provides the least magnification of the chest.	
____ 9. If the patient's movement is not restricted, this projection should be performed.	
____ 10. Requires the least movement of the patient.	

7-3. Surgical Radiography

As was the case in the section on bedside radiography, we will not discuss the specific exposure factors, grid use, etc., during surgical radiography. We will focus our study on the wearing of surgical clothing, cleaning your mobile unit, and your general actions inside the operating room. After that, we will examine some general guidelines that apply to the performance of the radiographic examinations.

457. State why special clothing is worn in the operating room, why nylon or similar materials should not be worn in the operating room, and how you are connected to ground when properly wearing operating room shoe covers.

Surgical Clothing. To reduce the amount of bacteria introduced into the operating room and to prevent the buildup of static electricity, you must change into special surgical clothing.

General clothing. The special clothing includes a shirt and trousers, or dress, cap, and mask. The shirt, trousers, and dress are usually made of cotton to prevent the buildup of static electricity. The cap and mask may be made of cotton, or they may be the disposable type. Since nylon or similar materials may cause static electricity, undergarments made of these materials should not be worn in the operating room.

Shoe covers. You must also wear special shoe covers when in the operating room. These shoe covers serve two purposes. One purpose is the same as that already mentioned for the remainder of the surgical clothing—they reduce the amount of bacteria introduced into the operating room. The second purpose is to prevent the buildup of static electricity. The covers perform the latter function by grounding you. There are several types of covers, and all of them have a conductive sole to which is attached a conductive strap. The end of the strap is inserted inside your sock so that it is in contact with your skin—thus grounding you. Some operating rooms use a device that tests you to determine whether or not you are properly grounded.

Operating room policies. Due to the preference of the chief of surgery, the physical arrangement of the surgical suite, and other variables, clothing policies may vary from one hospital to another. For this reason, you, as a technician or supervisor, should insure that you and your personnel understand the procedures used in *your* hospital, and should see that they are carried out properly.

Exercises (457):

1. Why must special surgical clothing be worn in the operating room?

2. Why shouldn't you wear nylon or similar undergarments in the operating room?

3. How are you connected to ground when properly wearing operating room shoe covers?

4. Give two specific factors that may cause clothing policies to vary from one hospital to another.

458. Explain why and how your mobile unit should be cleaned before it is taken into an operating room, list three areas about the unit requiring special attention while they are being cleaned, and state why the special attention is necessary.

Cleaning the Mobile Unit. In keeping with our previous discussion of reducing the bacteria introduced into the operating room, it follows that you must clean your mobile unit before taking it inside. This cleaning should consist of thoroughly wiping the entire unit down with hand towels soaked in an antiseptic solution provided by operating room personnel.

Contrary to what many technicians believe, sufficient cleaning of your portable unit is important. This is not too difficult to understand when you consider that the tube head is usually positioned directly over the operative site. Even though the site is usually covered with sterile drapes when you perform your radiographs, particles of dust falling from your tubehead may contaminate the sterile area. Some surgeons prefer that you cover the tubehead with a sterile pillow case or sheet of clear plastic *after* the machine is cleaned. This, of course, reduces the danger of contamination. Clear plastic may be preferable because it permits visualization of the light field from your collimator.

Other parts of your mobile unit requiring special attention during the cleaning procedure are the wheels and power cord. These, of course, are probably the dirtiest parts since they are repeatedly in contact with the floor.

Exercises (458):

1. Why should your mobile unit be cleaned before it is taken into an operating room?

2. How should your mobile unit be cleaned before it is taken into the operating room?

3. List three areas about your mobile unit requiring special attention when being cleaned, and in each case specify why attention to these areas is important.

4. After wiping your mobile unit down, how can you further prevent contamination of the operating site?

459. Name five persons or parts of the operating room in the sterile area and three persons or parts in the nonsterile area.

Actions Inside the Operating Room. During "open" surgery, the operating room is considered to be divided into two areas: sterile and nonsterile.

Sterile area. The sterile area is concentrated about the operating site. Included in this area is a certain portion of the patient, the surgeon and his immediate assistants, the surgical instruments, and the tables, trays, and stands containing the instruments.

Nonsterile area. The nonsterile area includes the anesthetist, you and your mobile unit, and various other portions of the operating room. As you are performing the radiographic examination, your main interest insofar as contamination is concerned is to keep from contaminating or contacting any part of the sterile area. It is usually good practice to extend the horizontal tube arm as far as possible so that when the tubehead is positioned over the patient, the remainder of the unit is remote from the table.

Exercises (459):

1. Name five persons or parts of the operating room in the sterile area.

2. Name three persons or parts of the operating room in the nonsterile area.

460. Point out significant factors affecting the performance of radiographic examinations in the operating room.

Performing the Examination. Numerous surgical procedures require radiographic support. It would be impractical to discuss all of them in this CDC. Instead, we will only discuss some of the most common procedures, as well as some general considerations that apply.

Speed. Surgeons and anesthetists or anesthesiologists like to accomplish surgery as quickly as possible so that the patient remains under the influence of the anesthetic for a minimum time. During some surgical procedures, the surgeon cannot continue until he examines the radiographs. This means that you should act quickly when performing the radiographic examination and return from your darkroom with the radiographs as quickly as possible.

You can, of course, reduce the delay caused by film processing by using Polaroid films and the accompanying processor. While you cannot use these films for all examinations, you can use them for many, especially open and closed reductions of the extremities.

Accuracy. Whenever you must repeat a radiograph made in the operating room due to the quality of the film, you are, in effect, increasing the length of the operation. Accordingly, the patient remains under the anesthetic for a longer time. Exposure and positioning are critical. Incorrect exposure is the most common reason for repeat radiographs made in the operating room. Incorrect or incomplete technique charts contribute to the problem at times, so try to maintain correct, complete mobile-unit charts. Incorrectly estimating the thickness of the part also leads to incorrect exposure. Measure the patient, if possible. It is not much of a problem to measure the patient the day before the surgery if the operation is scheduled—and many are scheduled in advance.

Scout film. Since many radiographs are repeated because of incorrect exposure, a scout film should be accomplished when possible. Naturally, a scout film need not be made for open or closed reductions of the extremities (excluding the hip). For a hip-nailing procedure, when a lateral projection (Danlius-Miller described in Chapter 4, Volume 2) is required, you should always perform a scout film and leave the mobile unit in place once the scout is accomplished. Also, for certain abdominal radiographs, such as an operative cholangiogram, you should always perform a scout film.

Aligning the X-ray tube to the grid. At times, it may be difficult to align the X-ray tube to the grid so that grid cut-off due to lateral decentering is prevented. The reason for the difficulty is that, because of the extent to which the patient is draped, you may not be able to tell where the center of the grid is located. (NOTE: This discussion is based on the assumption that you perform a properly aligned scout film for an operative cholangiogram, for example, and remove the unit from the immediate vicinity of the patient, thereby necessitating recentering the tube to the grid for the remaining radiographs.) One way to help prevent grid cut-off is to use a grid with a lower ratio, which, as discussed in Volume 1, increases the tolerable amount of lateral decentering.

Some technicians prefer to mark the location of the wheels on the floor when performing the scout film, so that they can return the mobile unit to the same location. Naturally, the position of the X-ray tube with respect to the grid must be correct for the scout radiograph if this procedure is to be helpful.

Exercises (460):

1. Why is it important for you to complete a radiographic examination in the operating room quickly and accurately?

2. How can you reduce the delay caused by film processing when reductions of the extremities are accomplished?

3. What is the most common cause of repeat radiographs in the operating room? What can you do to help prevent these repeats?

4. Name two surgical procedures requiring a scout film.

5. Why is it sometimes difficult to align the X-ray tube to the grid when performing radiographs in the operating room?

6. How can you increase the lateral decentering tolerance of the grid when performing a grid radiograph in the operating room?

7. Describe one way to properly align the tube to the grid for a later radiograph if they were properly aligned for the scout film.

Film Duplication and Subtraction

BOTH FILM duplication and subtraction are simple procedures to perform if you have one of the various commercial printers in your department. And if you have a continuous need to duplicate radiographs or perform subtraction, you should have a printer on hand. However, if you only occasionally perform either of these procedures, you can do very well by understanding the principles involved and by using your own "homemade" device. In this chapter, we will discuss the principles involved in film duplication and subtraction, and the construction and use of a special cassette to perform these two procedures.

8-1. Film Duplication

Our study of film duplication begins with a look at the principles of solarization. After that, we will examine specific procedures for duplicating radiographs.

461. Given a list of statements about solarization and its application to duplicating radiographs, indicate which are true and which are false.

Principles of Solarization. Before we define solarization, let's look at a characteristic curve of typical X-ray film. (See fig. 8[illegible].) As you recall, the reaction of the film to exposure, either light photons or X-ray photons, begins at the toe of the curve and proceeds along the slope to the shoulder. Along the curve, the density of the film increases as the exposure increases.

When the density of the film reaches the maximum, shown by the leveling off of the shoulder of the curve, additional exposure *reduces* the density of the film. The phenomenon that causes this decrease in density is called solarization. Notice in figure 8-2 that an extension of the characteristic curve shows the density to steadily drop as the exposure increases.

To see how solarization can be used to duplicate a radiograph, let's assume that you take an unexposed standard X-ray film, place it beneath a radiograph, and expose both of the films to white light for a very short time. After the X-ray film is processed, the information on the original radiograph appears, but the tones are reversed, as

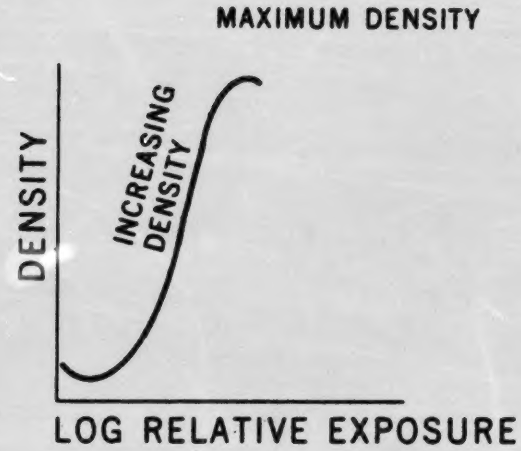

Figure 8-1. Typical characteristic curve of an X-ray film.

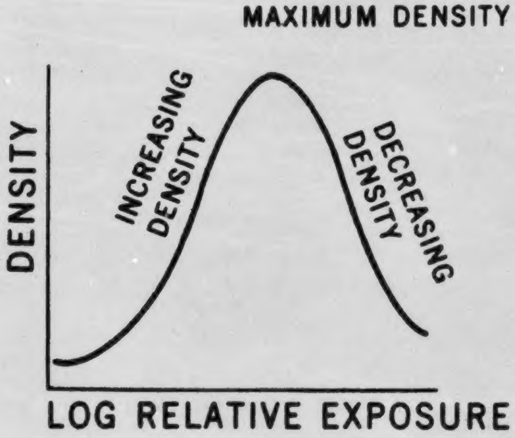

Figure 8-2. Extension of the characteristic curve showing the drop in density with increasing exposure caused by solarization.

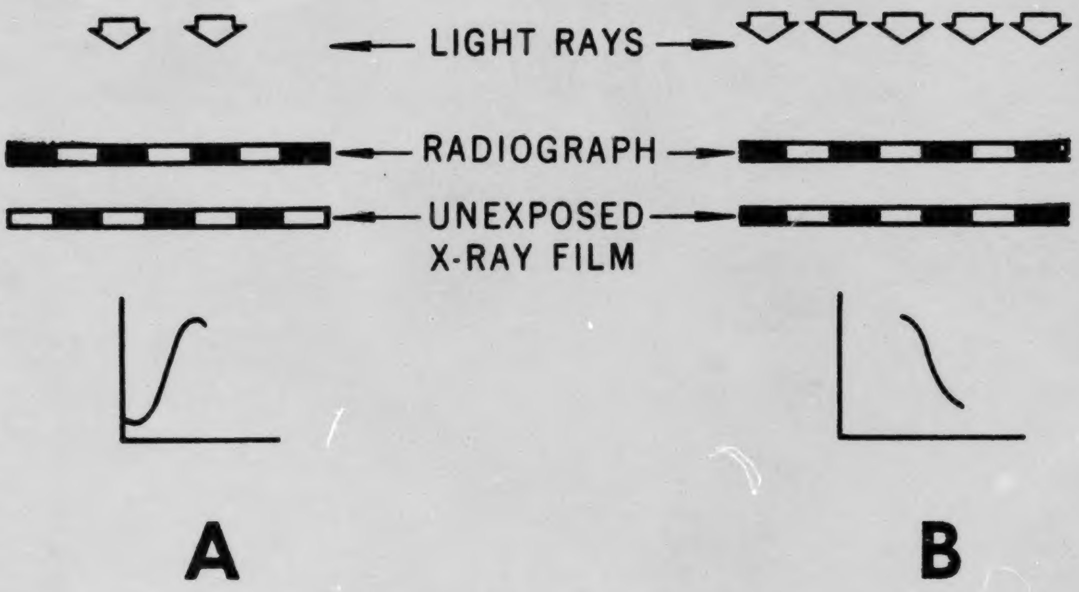

Figure 8-3. Comparison of the densities of a duplicated image using exposures in the characteristic curve and solarization ranges.

shown in figure 8-3,A. The black areas appear white, and the white areas appear black. This image reversal is due to the amount of exposure in the characteristic curve range where more exposure provides greater density. If both films are subjected to considerably more light, as shown in figure 8-3,B, the processed film shows the image of the original radiograph duplicated so that the black areas are black and the white areas are white. The reason for the exact tonal duplication is that the light exposure in now in the solarization range, where greater exposure to the film causes less density. Consequently, solarization allows you to copy a radiograph showing exact tonal duplication.

You can copy a radiograph by following the general procedure just discussed, using either sunlight or artificial light. However, the duplicate would not provide good detail because a standard X-ray film does not reproduce detail sufficiently during solarization due to the composition of the film.

Duplicating Film. Most film manufacturers make a *duplicating film* to be used specifically for copying radiographs, and you should use this type of film. Duplicating film differs from standard X-ray film in that it has emulsion on one side only, and the emulsion is already solarized. The response of the emulsion to exposure can be compared to a standard X-ray film that has been pre-exposed to the maximum density or to the shoulder portion of its characteristic curve.

Most brands of duplicating film are designed to be exposed with ultraviolet light, but some are designed to be exposed by white light. In either case, use the recommended light source.

Exercises (461):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. An increase in exposure always increases film density.

T F 2. Solarization can cause a high exposure to produce low density.

T F 3. If a radiograph is duplicated using a standard X-ray film, the amount of exposure determines the tonal relationships.

T F 4. If a radiograph is duplicated using a standard X-ray film, and the reproduced tones are the same as those of the radiograph, solarization did not influence the outcome of the tones.

T F 5. Duplicating radiographs using standard X-ray film produce good detail on the duplicate.

T F 6. Radiographs should be copied on duplicating film.

T F 7. Duplicating film responds to exposure in the same way as conventional X-ray film does.

T F 8. Solarized duplicating film should be used with the exposure source for which it is designed.

462. Answer key questions about the procedure for duplicating radiographs.

Duplicating a Radiograph. Now let's discuss a procedure for duplicating a radiograph. The first item you will need, other than a duplicating film, is a special cassette.

Glass front cassette. The special cassette you will need can easily be constructed from a standard cassette. (A single 14 by 17 cassette will be sufficient, but you can make one for each size radiograph that you copy.) Simply remove the bakelite front of the cassette and replace it with a transparent sheet of regular glass or plexiglass and remove the intensifying screens. Keep the glass clean and do not allow it to become scratched, since glass that is soiled and scratched causes artifacts on the duplicate.

To load the cassette, place the radiograph to be copied in the cassette first so that it is in contact with the glass front. Place the duplicating film in the cassette with the emulsion against the radiograph—the emulsion is on the "dull", not the "glossy" side of the film. Close, even contact must exist between both films when the cassette is closed to prevent loss of detail.

Light source. As mentioned before, you should use the type of light (ultraviolet or white) recommended by the manufacturer. Fluorescent or incandescent lamps may be used. Good results can be obtained by using an ordinary radiographic viewbox. Ultraviolet lamps can be obtained that can be used in your viewbox, and, in case of white light sensitive duplicating films, the viewbox can be used with the standard fluorescent lamps. You can also use certain incandescent lamps emitting white light as recommended by the film manufacturer.

Exposure time and source to film distance. Exposure time and source-to-film distance are closely related to each other since the intensity of the light diminishes as the source-to-film distance increases. Exposure time is usually in the neighborhood of a few seconds, while the source-to-film distance may reach to 40 inches. Each film manufacturer makes specific recommendations pertaining to these two factors—follow them.

Evaluation of the duplicate. Although you should initially follow the manufacturer's recommended exposure time, do not hesitate to vary your exposure if the duplicates are not satisfactory. Certain factors such as line voltage and processing may necessitate different exposures. Keep in mind that excessive exposure produces a light image and insufficient exposure produces a dark image. Obviously, this is due to the solarized duplicating film. Accordingly, you can also produce a duplicate with more or less density than the original by varying the exposure time.

Exercises (462):

1. Explain how a special cassette is made from a standard cassette.

2. Why should the cassette front be kept clean and free of scratch marks?

3. How should the two films (radiograph and duplicating film) be placed in the cassette?

4. Why should there be close, even contact between the radiograph and duplicating film?

5. What type of light source should be used to expose the cassette?

6. What specific exposure time and source-to-film distance should you use?

7. If a duplicate of a radiograph is too dark, how can the exposure be corrected on a subsequent duplicate?

8. If a radiograph is initially too light, can you produce a duplicate which is darker? How?

8-2. Subtraction

Subtraction is a procedure that eliminates unwanted shadows from a radiograph. Specifically, the technique is usually used to eliminate all of the anatomical structures from an angiogram, leaving only an image of the contrast-filled vessels. Several methods of subtraction have been developed and used sucessfully, including electronic subtraction using television pickup tubes that display the vessels on a monitor. Subtraction fluoroscopy also is being performed with some success.

As stated in the introduction to this chapter, this method of subtraction is meant for the department that only occasionally performs the technique—although the basic principles apply to most

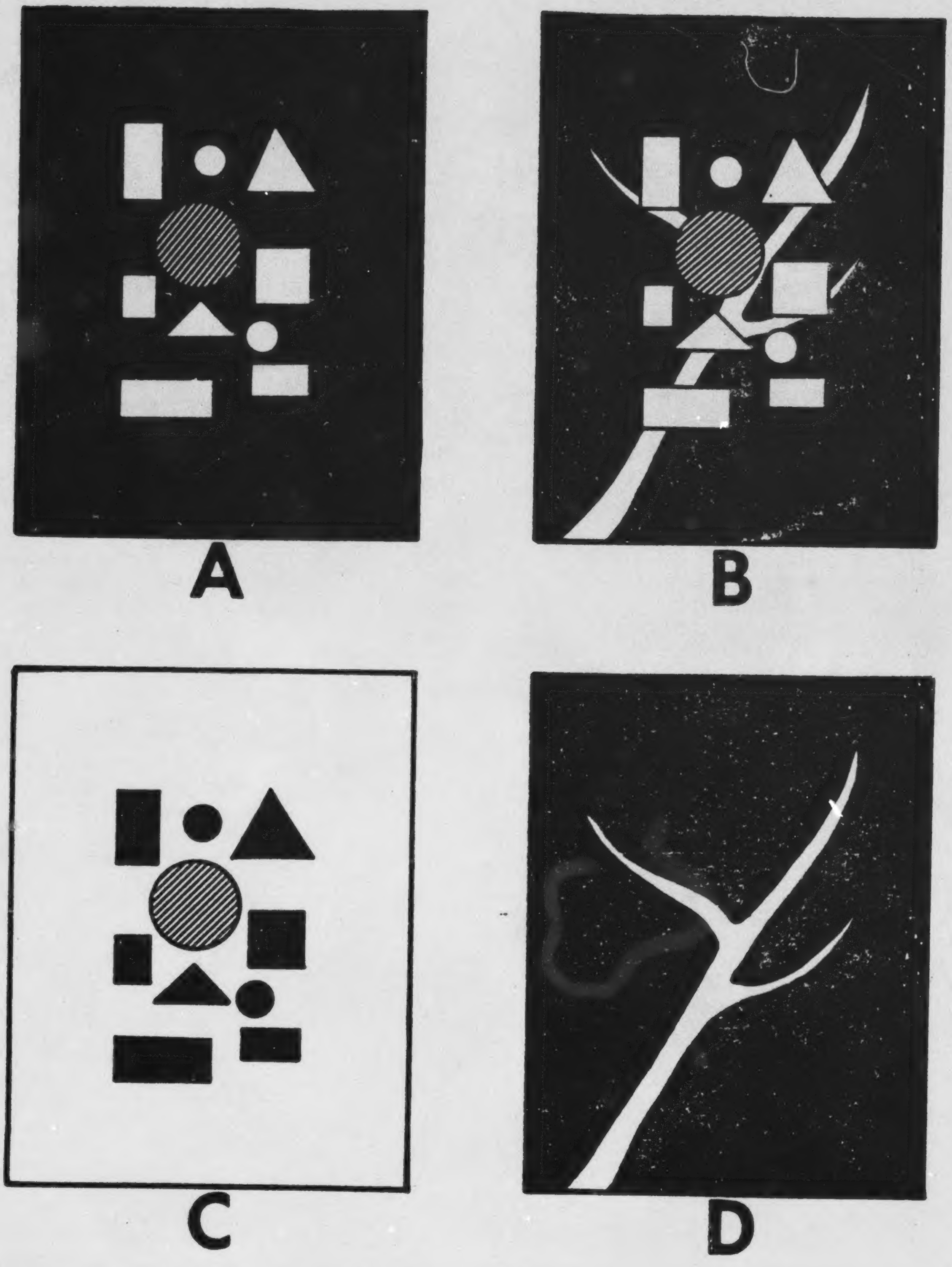

Figure 8-4. The process of subtraction.

commonly used methods. We begin our discussion with a look at the principles of subtraction.

463. Supply key words in a series of statements about the principles involved in the subtraction process.

Principles of Subtraction. Basically, subtraction removes the unwanted shadows from a radiograph by reducing or eliminating the contrast between those shadows. To illustrate how the contrast is affected, we have assembled some drawings in figure 8-4. Assume that drawing A represents a *scout film* taken before the injection of the contrast medium during an angiogram. The figures in the drawing would represent the bony structures. (NOTE: In actuality, the bony structures would be represented by more than the two densities shown.) In drawing B we have added three more structures that represent the contrast-filled vessels on an *angiogram*.

Drawing C represents a negative of the scout film and is called the subtraction *mask*. The tones of the mask are reversed from those of the scout—that is, the dark areas on the scout are light on the mask, and the light areas on the scout are dark on the mask. The large circle, which was gray on the scout film, is also gray on the mask.

Now if we superimpose films B and C, the appearance resembles drawing D in the figure—a dark background with the contrast-filled vessels appearing alone and light. Thus, the bony structures that may interfere with the interpretation of the vessels are canceled out or "subtracted" from the angiogram.

As mentioned before, the unwanted shadows are removed by reducing or eliminating the contrast. Think for a minute about what happens to the densities. The dark structures or areas become dark when superimposed over the light structures. Likewise, gray structures superimposed over gray structures become dark. The contrast-filled vessels that are included only on the angiogram remain visible. Consequently, except for the contrast between the vessels and the remaining dark background, the contrast on the angiogram is more or less eliminated.

Exercises (463):

Insert an appropriate word in each of the following blank spaces in the statements below concerning the principles of subtraction.

1. Subtraction removes structures that may interfere with interpretation by __________ or __________ the __________ between those structures.
2. The __________ __________ is considered a reverse tonal copy of the scout film.
3. Gray structures on the scout film are __________ on the mask.
4. Superimposition of the ______________ and __________ produces high contrast between the contrast -filled vessels and background.
5. The mask, in effect, causes the background around the contrast-filled vessels to appear ____________________.
6. Structures are subtracted because the __________ of each structure become equal.

464. Give selected details significant to the procedure for performing subtraction.

Performing Subtraction. Let us now discuss a simple method for performing subtraction. The only equipment you will need for this method is a supply of subtraction film, a 10- or 15-watt incandescent light bulb, and a glass-front cassette (the same as the one used to duplicate radiographs). We will begin with a closer look at the scout film.

Scout film. One of the key factors that influences the degree of subtraction achieved is whether or not there is part-motion between the scout film and the angiogram. Good subtraction of the structures can be achieved only if the structures on the mask and angiogram (except for the vessels) are exactly superimposed. If the patient moves between the scout and angiogram, you will not be able to precisely superimpose the structures. For this reason, subtraction is usually accomplished in conjunction with an examination performed with an automatic film changer, where the time lapse between the scout film and the angiogram is minimal, thereby reducing the possibility of patient movement.

Obviously, there will be times when the patient does move even when you use an automatic changer. Movement may be simply due to the patient's condition or it may be due to the feeling he experiences as the contrast material is injected. When movement occurs that prevents you from superimposing all of the structures, try to superimpose those in the area of greatest interest and forget about the rest.

Mask. To make the subtraction mask, place the scout film in the special cassette against the glass front, then put the subtraction film in the cassette with the emulsion (dull) side against the scout. Expose the cassette to a 10- or 15-watt incandescent light bulb at a distance of 6 feet. Exposure time usually ranges from 2 to 30 seconds, depending upon the brand of film, the intensity of the light, and the density of the scout film.

Another key factor in the subtraction process is whether or not the differences between the densities on the scout are maintained on the mask. For example, if the densities of two bony structures on a scout film are 1.5 and 0.5, the density ratio is 3 to 1. To eliminate the contrast between those structures, their respective densities on the mask must exist in a ratio of 1 to 3—for example, 0.5 and 1.5.

Subtraction print. So far we have only discussed superimposing the mask and the angiogram on a viewbox so that the radiologist can interpret the results directly. Some radiologists may prefer to make a subtraction *print* of the results.

To make the print, place the superimposed mask and angiogram (taped together) in the special cassette with the mask against the glass. Place either a standard X-ray film or a subtraction film on top of the angiogram. The standard film usually results in higher contrast. If a subtraction film is used, place its emulsion side against the angiogram. Expose the film to the same light source at the same distance as before. Exposure time is determined by trial and error, but you will need a longer exposure than when you made the mask because you now have two films between it and the light source. The subtraction print produced in this manner will reveal the contrast-filled vessels to be dark against a light background.

Exercises (464):

1. Why is it important that there be no part motion between the scout film and the angiogram?

2. Why is subtraction usually accomplished for examinations performed with an automatic film changer?

3. If part motion occurs between the scout film and the angiogram, what action should you take when performing the subtraction?

4. How do you make the subtraction mask?

5. What relationship must exist between the densities of the structures on the scout film and the densities of the structures on the mask (other than reverse tones)?

6. On what types of film can a subtraction print be made?

7. What films are placed inside the special cassette to make a subtraction print and in what order?

8. Why do you need more exposure when making the print than when making the mask?

9. How do the tones of the subtraction print compare with those seen when the mask and angiogram are viewed directly?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

400 - 1. a, d.
400 - 2. c.
400 - 3. e.
400 - 4. b.
400 - 5. g.
400 - 6. h.
400 - 7. e.

401 - 1. Fibrous and glandular (fibroglandular) tissue are about equal; fatty tissue is the least dense of the three types.
401 - 2. Atrophic, because it consists entirely of fatty tissue.
401 - 3. Adolescent and lactating.

402 - 1. T.
402 - 2. F. While this statement is partially true, it is incomplete. Remember the focal-spot must also be able to withstand the heat generated by the exposures.
402 - 3. T.
402 - 4. F. The single exposure rating of the tube must also be considered.
402 - 5. T.
402 - 6. T.
402 - 7. T.
402 - 8. F. It has a small aperture.
402 - 9. T.

403 - 1. The detail produced on the radiographs is inadequate.
403 - 2. Standard films are coarse-grained, while industrial or mammographic films are fine-grained.
403 - 3. Obtain commercial film packages or combine films of various speeds in a direct exposure holder.
403 - 4. It permits good visualization of both thick and thin portions of the breast from a single exposure.
403 - 5. Process them according to the film manufacturer's instructions.
403 - 6. High detail screens made especially for mammography.
403 - 7. A disadvantage is loss of detail; an advantage is reduction of part motion.

404 - 1. Twenty to 30 since the absorption properties of fibroglandular, fatty, and pathological tissue are nearly equal. The low kVp range is necessary to provide adequate contrast on the radiograph.
404 - 2. Up to 50. A certain amount of muscle tissue must be penetrated.

405 - 1. FFD, film speed, and whether or not intensifying screens are used.
405 - 2. Part motion. By using the shortest exposure time possible.
405 - 3. Twenty to 40 inches.
405 - 4. Advantages are: (1) increased detail and (2) lower patient skin dose. Disadvantage: requires more exposure.
405 - 5. Advantage: requires less exposure. Disadvantages: (1) detail loss due to increased magnification and (2) higher skin dose to the patient.

406 - 1. F. On the craniocaudal and the mediolateral projections.
406 - 2. T.
406 - 3. T.
406 - 4. F. Firm contact is important so that the posterior portion of the breast is included on the film.
406 - 5. T.
406 - 6. T.
406 - 7. T.
406 - 8. T.
406 - 9. F. It depends upon the relative position of the tail of the breast.
406 - 10. T.

CHAPTER 2

407 - 1. Two types of tissue (gonadal and immature growing) which are highly susceptible to irreversible alteration from exposure to ionizing radiation are present in the patient.
407 - 2. Improper positioning can prevent accurate evaluation of the radiographs.
407 - 3. Repeat examinations due to improper positioning.
407 - 4. (1) Ask the patient to inform you when there is no noticeable fetal motion, (2) have the patient breathe deeply several times and suspend respiration on inhalation before the exposure, and (3) use the shortest exposure time possible.
407 - 5. Use high-speed screens and films, use high kVp and low mAs, and use reliable exposure techniques.

408 - 1. T.
408 - 2. F. Visualization can occur as early as 12 weeks.
408 - 3. F. Exposure is more dangerous at 14 weeks.
408 - 4. F. Superimposition of the sacrum and fifth lumbar vertebra is important.
408 - 5. F. Technicians do need to recognize a fetus on all radiographs taken of the pelvic area on procreative

patients. Sometimes a physician does not know that his patient is pregnant, and you can prevent excessive exposure to the new fetus by identifying the fetal skeleton on other radiographs.

408 - 6. T.
408 - 7. T.
408 - 8. T.
408 - 9. F. Demonstration of the fetal skull bones is important because overlapping of the bones can be a sign of fetal death.
408 - 10. T.
408 - 11. F. Anencephaly is absence of the skull.

409 - 1. Radiologist; obstetrician.
409 - 2. Iliac crests.
409 - 3. Symphysis pubis.
409 - 4. AP; PA.
409 - 5. Knees; forearms.
409 - 6. PA; without.
409 - 7. PA.
409 - 8. Posterior.
409 - 9. Obliquity; PA; AP.
409 - 10. Position; comfort.

410 - 1. Twenty cm ir diameter and 5 cm thick.
410 - 2. On the anterior or posterior uterine wall.
410 - 3. In the lower segment of the uterus.

411 - 1. (1) The density of the placenta is nearly equal to other surrounding tissues. Use soft tissue technique—relatively high mAs and low kVp. Discuss the technique with the radiologist since it results in a relatively high absorbed dose to the mother and child. (2) The thickness of the abdomen in the lateral position varies from the posterior to the anterior portions. Difference in thickness must be compensated for so that the entire film shows the same density.

412 - 1. With the thick portion over the anterior abdomen.
412 - 2. Aluminum, copper, and barium sulfate.
412 - 3. Mix the barium sulfate with molding clay or petrolatum. Spread over a 0.5 mm piece of aluminum so that the filter is 2.0 mm thick on one end and tapers to almost no thickness of barium on the other end.
412 - 4. By placing a piece 1 to 3 mm thick in the primary beam over the anterior half of the abdomen.
412 - 5. Two. Fast and slow.
412 - 6. With the fast screens under the posterior portion of the abdomen.
412 - 7. Place the paper inside the cassette so that it covers one-half of the film on one side only. Place the covered portion of the film under the anterior portion of the abdomen.

413 - 1. The relationship between these two structures is evaluated for placenta praevia.
413 - 2. Rotation of the pelvis projects the fetal head lateral to the midline.

414 - 1. (1) AP diameter—inlet; lateral projection.
(2) AP diameter—midpelvis; lateral projection.
(3) AP diameter—outlet; lateral projection.
(4) Transverse diameter inlet; AP projection.
(5) Transverse diameter midpelvis; AP projection.
(6) Transverse diameter outlet; AP projection.

415 - 1. To determine the degree of magnification of the pelvic diameters.
415 - 2. Between the gluteal folds. The level is the same as that of the AP pelvic diameters.
415 - 3. At the same level as the ischial tuberosities. The level is the same as that of the transverse pelvic diameters.
415 - 4. Palpate the upper margin of the symphysis pubis, and set the perforated ruler 10 cm below that margin.

416 - 1. It would cause the AP pelvic diameters to measure longer than they actually are; consequently, the pelvis may be judged to be adequate for delivery, and may not actually be adequate. Evaluation of the pelvis is inaccurate because the spaces between the ruler dots are magnified less than they should be.
416 - 2. It would cause the AP diameters to measure shorter than they actually are, which could cause the pelvis to be judged inadequate for delivery, although it may actually be adequate. The mistaken diagnosis is caused by the spaces between the ruler dots being magnified more than they should be.
416 - 3. Same answer as for exercise #1 (above) except that the transverse diameters, instead of the AP diameters, are affected.

417 - 1. a. (1) Failure to properly align the pelvis.
    (2) Obscures the ischial spines and prevents accurate measurement of the transverse diameter of the midpelvis—also makes other transverse measurements difficult.
    (3) Adjust the median plane perpendicular to the table.
b. (1) Failure to include the ruler on the film.
    (2) Magnification of the transverse diameters cannot be determined and the radiograph is of no use.
    (3) Center the film $1^{1}/_{2}$-inches above the symphysis pubis.
c. (1) Overexposure of the film.
    (2) May prevent identification of bony landmarks between which transverse diameters are measured.
    (3) Measure through the CR.

418 - 1. a. (1) Positioning the patient so that the pelvis is anteriorly rotated.
    (2) Shortens AP pelvic diameters and results in low measurements.
b. Perform the lateral erect or elevate the anterior abdomen, superimpose the legs exactly, and place supportive material between the knees and ankles.
c. (1) Superimposing the femurs over the symphysis pubis.
    (2) Anterior ends of the AP diameters are not visualized.
    (3) Extend the femurs.

CHAPTER 3

419 - 1. Radiography of sections of the body.
419 - 2. Radiograph produced by tomography.
419 - 3. A connecting rod which couples the tube and film carrier (cassette tray).
419 - 4. The point about which the lever rotates or pivots.
419 - 5. Body layer which appears sharpest on the tomogram.
419 - 6. Unsharp body area outside (above or below) the focal plane.

419 - 7. Distance in inches the tube travels during exposure.
419 - 8. Speed of tube travel (usually expressed in inches per second).
419 - 9. Angle in degrees of the tube travel during exposure.
419 - 10. Tomography with a small exposure angle—less than 10°.

420 - 1. Sinusoidal.
420 - 2. Elliptical.
420 - 3. Circular.
420 - 4. Spiral.
420 - 5. Hypocycloidal.
420 - 6. Random.
420 - 7. Linear.

421 - 1. Its relative position on the film is the same throughout the exposure.
421 - 2. Its relative position on the film shifts during the exposure.
421 - 3. Objects located in the focal plane are not blurred because their relative positions on the film do not change during the exposure.

422 - 1. Layer; section.
422 - 2. Section thickness.
422 - 3. Sharp; unsharp.
422 - 4. More.
422 - 5. Thicker.

423 - 1. T.
423 - 2. F. A long amplitude produces a thin section.
423 - 3. F. There is. (The longer the FFD at a given amplitude, the less the exposure angle.)
423 - 4. F. The structures are projected by different exposure angles. The farther a structure is from the focal plane, the greater the exposure angle.
423 - 5. T.
423 - 6. T.
423 - 7. T.

424 - 1. Three.
424 - 2. Bottom (remote from tube). Top (nearest the tube).
424 - 3. Photons are absorbed as they pass through the films, screens, and interspace material. Variable speed screens compensate for the absorption.
424 - 4. 0.5 mm.

425 - 1. Each film has, in effect, its own fulcrum due to the space between the films.
425 - 2. 15 cm. 11 cm.

426 - 1. Because of the relatively low book exposure compared to the combined exposures of the individual exposures.
426 - 2. No, because the exposure required for the book is more than that required for a single exposure due to the speed of the top pair of intensifying screens.
426 - 3. It reduces it.
426 - 4. (1) The lower films provide less good detail than the upper films because the lower intensifying screens are faster.
(2) Contrast is reduced on the lower films because more scattered photons are present.

427 - 1. Approximately 150 mAs.
427 - 2. Approximately 100 mAs.
427 - 3. The tissue thickness is greater due to the angle of the tube.

428 - 1. Sec = 3.
428 - 2. Amplitude = 8 inches.
428 - 3. Rate = 5 inches per second.

429 - 1. T.
429 - 2. T.
429 - 3. T.
429 - 4. T.

CHAPTER 4

430 - 1. No.
430 - 2. No.
430 - 3. No.
430 - 4. No.

431 - 1. At right angles to the predominant lines of the part.
431 - 2. Because this produces the maximum variation in the two views; the more variation, the better the stereoscopic effect.
431 - 3. Vertical, because the ribs are the predominant lines, and they lie horizontally.
431 - 4. Either across or with the longitudinal axis.
431 - 5. Decentering tolerance for the grid.
431 - 6. (1) Replace the grid with one of a lower ratio.
(2) Remove the grid and perform nongrid radiographs.
(3) Position the patient crosswise on the table (use a stretcher).
(4) Shift the tube longitudinally with the table if there is not much difference between the part axes.

432 - 1. Near.
432 - 2. Far.
432 - 3. Far.
432 - 4. Far.
432 - 5. Near.

433 - 1. Tube side.
433 - 2. Film side.
433 - 3. Tube side.
433 - 4. Film side.

434 - 1. 2-4.
434 - 2. 1-3.

435 - 1. Right eye—film #2; left eye—film #1.
435 - 2. Right eye—film #1; left eye film #2.

436 - 1. Two conventional viewboxes.
436 - 2. It is the most convenient method because no special apparatus is required.
436 - 3. Left.
436 - 4. The direction of tube shift is parallel with your interpupillary line.
436 - 5. Film side.

437 - 1. No. The films are reversed from their correct positions—the right eye film should be on the right side and the left eye film should be on the left side.
437 - 2. No. The tube sides are toward you; they should be against the viewboxes.

CHAPTER 5

438 - 1. AP or PA and lateral.
438 - 2. No. The physician determines the location of the foreign body by examining the part while it is in the position it was in when the radiographs were made.

He can duplicate exactly the AP, PA, or lateral positions. However, he may not be able to duplicate oblique projections.

438 - 3. It enables the physician to determine the precise proximal/distal location of the foreign body.

438 - 4. (1) Tape a metallic marker such as an "X" or "O" directly over the entrance wound, if one is visible.

(2) Place an arrow directly on the film holder in the same transverse plane, pointing to the entrance wound. The arrow should not be superimposed over any tissue.

(3) Make a mark on the patient's skin if an entrance wound is not visible and align an arrow on the holder as described above.

439 - 1. F. You also center the film and align the CR to the mark.
439 - 2. F. They appear superior/inferior to each other since the tube is shifted longitudinally.
439 - 3. F. Collimation is important. The primary beam should be reduced to a size slightly larger than the foreign body to insure correct placement of the skin mark.
439 - 4. T.
439 - 5. T.
439 - 6. F. The tube-skin distance need not be recorded.
439 - 7. F. The first exposure uses the CR to project the image. The second exposure does not.

440 - 1. FBD = 238 mm (IS = 10 mm).
440 - 2. FBD = 128 mm (IS = 15 mm).

441 - 1. 7.
441 - 2. 2.
441 - 3. 4.
441 - 4. 5.
441 - 5. 3.
441 - 6. 8.
441 - 7. 1.
441 - 8. 6.
441 - 9. 3, 4.
441 - 10. 1, 5, 8.
441 - 11. 2.
441 - 12. 6.
441 - 13. 7.

442 - 1. 1; 2.
442 - 2. The tray is inserted into the headrest tunnel to the red mark nearer the cassette for the first exposure and to the second red mark for the second exposure.
442 - 3. True lateral.
442 - 4. First exposure—10 mm anterior to the most anterior surface of the cornea or to the ball on the localizer. Second exposure—midway between the ball and cone.
442 - 5. The object should be in the same vertical plane as the patient's eyes and in the same horizontal plane as the median plane of his head.
442 - 6. The center of the ball is in the same vertical and horizontal planes as the center of the pupil and/or cornea.
442 - 7. Approximately the thickness of the eyelid.
442 - 8. Before.
442 - 9. 10 mm.
442 - 10. Cushion the mechanism with your hand and allow it to drop back gently to prevent the abrupt return of the mechanism from startling the patient.
442 - 11. 15° to 25° cephalic.

443 - 1. It allows the radiologist to determine the *exact* location of the foreign body. This enables the ophthalmologist to know the exact location of the body and remove it with less chance of additional damage to the eye.
443 - 2. Explain the details of the examination to him.
443 - 3. The patient is probably uncomfortable and experiencing eye pain due to the presence of the foreign body. The quicker you perform the examination, the more successful it will be.
443 - 4. The ball and cone and their supporting rods must be exactly superimposed on the radiograph.
443 - 5. The ball and cone must be separated on the radiograph.
443 - 6. The foreign body localization may be incorrect.
443 - 7. Measure the distances from the patient's eyes to the wall located beyond the top of his head, and from his eyes to the floor. Transpose those distances to the wall in front of the patient's face.

CHAPTER 6

444 - 1. (1) To determine the numerical length of a long bone.

(2) To determine the relative lengths of two opposite bones.

445 - 1. The CR is perpendicular to the film in both cases. For a conventional radiograph, the CR is directed to the middle of the part and film. For a scanogram, the CR is directed to each end of the bone.
445 - 2. The bone is magnified on the conventional radiograph; it is projected actual size on the scanogram.
445 - 3. The ends of the bone are projected by divergent portions of the primary beam on the conventional radiograph and by the CR (nondiverging beam) on the scanogram.

446 - 1. F. Because it is radiopaque, the kVp should be raised by 10.
446 - 2. T.
446 - 3. T.
446 - 4. F. The ruler and patient should never be moved, but the film *may* be moved, depending upon the method employed and if the tube is *always* shifted between exposures.
446 - 5. F. All scanograms are accomplished by AP projections.
446 - 6. T.
446 - 7. T.
446 - 8. T.
446 - 9. T.
446 - 10. T.
446 - 11. F. When performing an actual length scanogram without a ruler, the film must be long enough to project the entire length of the bone. The entire femur cannot be projected on a 10- by 12-inch film.
446 - 12. T.
446 - 13. T.

447 - 1. B. (C may also be correct, but you cannot tell from the information provided.)
447 - 2. None. (C may project a shorter image, but you cannot tell from the information provided.)
447 - 3. A. (C may also project a shorter image, but you cannot tell from the information provided.)
447 - 4. The CR for the lower X-ray field is aligned correctly. You cannot make any conclusions about the

CR alignment for the upper field because you cannot see the entire X-ray field. For all you know, the field may measure 10 or 15 inches from top to bottom.

448 - 1. b.
448 - 2. c.
448 - 3. b.
448 - 4. a.
448 - 5. c.
448 - 6. c.
448 - 7. c.
448 - 8. b.
448 - 9. a.

449 - 1. The lateral surface is shaved. The skin is cleaned and prepared, as directed by your radiologist. Surgical soap, alcohol, zephiran chloride, tincture of iodine, or a combination of these items may be used. The area is draped with sterile towels or sheets.
449 - 2. Water soluble.
449 - 3. a. 10 to 15 cc. b. 20 to 30 cc.
449 - 4. Air, oxygen, or carbon dioxide.
449 - 5. To keep dilution of the contrast medium to a minimum.
449 - 6. (1) By massaging the knee.
(2) By allowing the patient to stand and walk around.
(3) By wrapping the knee in an ace bandage.
449 - 7. Before the lateral radiographs are made in order to permit visualization of the quadriceps pouch.

450 - 1. T.
450 - 2. F. The PA and AP are usually taken with a 6° cephalic and a 3° caudal angle, respectively, to open the joint space.
450 - 3. F. Obliques of 30°, 45°, 60°, or 75° may be made.
450 - 4. F. Speed is important to accomplish the radiographs before the contrast medium disappears from the joint capsule.
450 - 5. T.
450 - 6. T.
450 - 7. F. It is difficult to determine the exact location of the joint space. You should have your radiologist mark the space under fluoroscopy.

CHAPTER 7

451 - 1. c.
451 - 2. c.
451 - 3. b.
451 - 4. a.
451 - 5. b.
451 - 6. a.
451 - 7. b, c.
451 - 8. c.
451 - 9. c.
451 - 10. a.
451 - 11. b, c.
451 - 12. a.
451 - 13. c.

452 - 1. (1) The patient's bed is electrically operated.
(2) Your mobile unit is in contact with the bed.
(3) A wiring defect exists in your unit so that the unit housing is not isolated from the circuitry.
(4) The patient's bed also has a wiring defect similar to that of your machine and is properly grounded.
(5) The patient is in contact with the metal framework of his bed.
452 - 2. (1) Properly ground your mobile unit.
(2) Do not radiograph a bedside patient with your mobile unit in contact with his bed.

453 - 1. An agent which could explode if exposed to a spark or flame.
453 - 2. Cyclopropane and ether.
453 - 3. Ether.
453 - 4. A room or an area in which an explosive agent is being used, and for a short time after use is continued.
453 - 5. A mobile unit that has been manufactured to reduce the possibility of sparking, arcing, or any other occurrence that could cause an explosion.
453 - 6. This change might be made in order to permit radiographs to be accomplished.
453 - 7. When informed by the anesthetist or anesthesiologist that conditions are safe. This usually occurs about 15 minutes after use of the explosive agent has been discontinued.
453 - 8. (1) NFPA (National Fire Protection Association).
(2) UL (Underwriters' Laboratories, Inc.).
453 - 9. WARNING: This X-ray unit shall not be used in the presence of explosive gases.
453 - 10. On the control panel of the unit where it will be readily visible to the operator when he energizes the unit.
453 - 11. Pressure sensitive paper which is approximately 3$^1/_2$ inches wide and 1 inch high. The letters should be one-eighth of an inch or more high.
453 - 12. When using the unit in the operating room.
453 - 13. Because the greatest concentration of the agent is near the floor.
453 - 14. They are designed so that the electrical connections are enclosed.
453 - 15. Arcing is most likely to occur at any connection when a plug is inserted into a receptacle.

454 - 1. 12 inches.
454 - 2. 0.25 mm.

455 - 1. Combustion.
455 - 2. Flash fire.
455 - 3. Turned off.
455 - 4. Remove; restart.
455 - 5. Condition.
455 - 6. In advance; quickly.
455 - 7. Tent; patient's head.

456 - 1. d.
456 - 2. a.
456 - 3. a, b, c, d.
456 - 4. a, b.
456 - 5. c.
456 - 6. a.
456 - 7. d.
456 - 8. a, b.
456 - 9. a.
456 - 10. d.

457 - 1. To reduce the amount of bacteria introduced into the operating room and to prevent the buildup of static electricity.
457 - 2. They may cause static electricity.
457 - 3. Through a conductive strap (which is in contact with your skin) attached to the conductive sole of the covers.

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457 - 4. The preference of the chief of surgery and the physical arrangement of the surgical suite.

458 - 1. To reduce the bacteria introduced into the operating room.
458 - 2. By thoroughly wiping it down with hand towels soaked in an antiseptic solution provided by operating room personnel.
458 - 3. (1) Tube head—it is usually positioned directly over the operating site.
  (2) Wheels—they are especially dirty because of their repeated contact with the floor.
  (3) Power cord—it is especially dirty because of its repeated contact with the floor.
458 - 4. Cover the tubehead with a sterile pillowcase or sheet of clear plastic.

459 - 1. (1) Surgeon.
  (2) Surgeon's immediate assistants.
  (3) Part of patient.
  (4) Surgical instruments.
  (5) Tables, trays, and stands containing instruments.
459 - 2. (1) Anesthetist.
  (2) You.
  (3) Your mobile unit.

460 - 1. To help reduce the overall operation time and, therefore, the amount of the time the patient is under the influence of the anesthetic.
460 - 2. By using Polaroid films and the accompanying processor.
460 - 3. Incorrect exposure. Maintain correct, complete, mobile-unit technique charts. Measure the patient if possible. Perform a scout film, if possible (except for most reduction radiographs of the extremities).
460 - 4. Hip nailing when a lateral projection is required and an operative cholangiogram.
460 - 5. The patient is draped to such an extent that you may not be able to tell exactly where the center of the grid is located.
460 - 6. Use a grid with a lower ratio.
460 - 7. Mark the locations of the wheels of the mobile unit on the floor when performing the scout film. Later, return the wheels to the same marks.

CHAPTER 8

461 - 1. F. An increase in exposure increases film density only to the point (shoulder portion of the characteristic curve) where maximum density is reached. After that, additional exposure decreases density.
461 - 2. T.
461 - 3. T.
461 - 4. F. Solarization did influence the outcome because the same tones were duplicated. If opposite tones had occurred on the duplicate, solarization would have had no influence on the outcome.
461 - 5. F. Because of its composition, standard X-ray film does not produce a duplicate with good detail.
461 - 6. T.
461 - 7. F. Duplicating film responds differently. The more exposure, the less the density, because the emulsion is solarized.
461 - 8. T.

462 - 1. Remove the bakelite front and replace it with a sheet of transparent glass or plexiglass. Remove the intensifying screens.
462 - 2. Glass that is soiled and scratched causes artifacts on the duplicate.
462 - 3. Place the radiograph in first so that it is against the glass front of the cassette. Place the duplicating film in next with the "dull" side against the radiograph.
462 - 4. To prevent loss of detail.
462 - 5. Ultraviolet or white, depending upon the recommendation of the manufacturer.
462 - 6. As recommended by the film manufacturer.
462 - 7. By increasing the exposure.
462 - 8. Yes. Use less than the normal exposure.

463 - 1. Reducing; eliminating; contrast.
463 - 2. Subtraction mask.
463 - 3. Gray.
463 - 4. Angiogram; mask.
463 - 5. Dark.
463 - 6. Densities.

464 - 1. Motion prevents exact superimposition of the mask and angiogram. Good subtraction of the structures occurs only if the structures on the mask and angiogram (except the vessels) are exactly superimposed.
464 - 2. Part motion is least likely to occur because of the short time between the scout film and the angiogram.
464 - 3. Try to superimpose the structures in the area of greatest interest.
464 - 4. (1) Place the scout film in the special cassette against the glass front.
  (2) Place the subtraction film in the cassette with the "dull" emulsion side against the scout.
  (3) Expose the cassette to a 10- or 15-watt incandescent light bulb at a distance of 6 feet. (Exposure time is usually 2 to 30 seconds, depending upon the brand of film, the intensity of the light, and the density of the scout film.)
464 - 5. The differences between the densities must be the same.
464 - 6. A standard X-ray film or a subtraction film.
464 - 7. (1) Mask—against glass front.
  (2) Angiogram—taped to the mask.
  (3) X-ray film or subtraction film.
464 - 8. You now have two films in front of the unexposed film.
464 - 9. They are reversed.

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STOP–

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.

2. USE NUMBER 1 OR NUMBER 2 PENCIL.

90370 03 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

SPECIAL TECHNIQUES

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers.* The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed.* Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

10-5

Multiple Choice

1. (400) The highly pigmented surface landmark which comprises a part of the breast's external structure is the

   a. areola. c. tail of the breast.
   b. adipose tissue. d. acini or terminal duct.

2. (400) Depending upon the patient's age and obstetrical condition, fatty tissue surrounds and is distributed in the breast's

   a. facia. c. glandular tissue.
   b. fibrous tissue. d. retromammary space.

3. (400) The radiographically significant structure of the breast that lies between the posterior portion of the mammary gland and the pectoral muscle is the

   a. mamma. c. tail of the breast.
   b. lactiferous duct. d. retromammary space.

4. (401) With regard to exposure requirements during mammagraphs, which, if any, of the three types of breast tissue is the least dense?

   a. Fatty tissue. c. Glandular tissue.
   b. Fibrous tissue. d. All three are about equal in density.

5. (401) Which type of breast listed below would require the most exposure when taking mammograms?

   a. Mature. c. Lactating.
   b. Atrophic. d. Menopausal.

6. (402) Tube requirements during mammography are such that, if at all possible, it is best to use

   a. a relatively small focal spot.
   b. NO cooling time between exposures.
   c. NO restrictions on the X-ray field.
   d. 2.0 mm of added aluminum filtration.

7. (402) What action should be taken pertaining to the total filtration in the primary beam when performing a mammogram?

   a. Use 1.5 mm aluminum.
   b. Use 0.5 mm over the minimum.
   c. Use the minimum and no more.
   d. Use the maximum when the kVp is below 50.

8. (402) How large an X-ray field should be used for mammography?

   a. As large as the breast.
   b. So that it covers the breast plus a 1-inch border.
   c. So that it covers the breast plus a 2-inch border.
   d. Less than 6 inches in diameter provided the breast is smaller.

9. (403) Why should fine-grained X-ray films be used for mammography in lieu of coarse-grained film?

   a. Detail is better.
   b. Contrast is high.
   c. Photoelectric absorption is eliminated.
   d. Slow processing produces better radiographs.

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10. (403) Why should a multifilm exposure be used for mammography?

   a. Less kVp is required.
   b. A single film may be fogged.
   c. Pathological processes are radiopaque.
   d. Both thick and thin portions are visualized.

11. (404) Why should low kVp be used for a mammogram?

   a. Low kVp lowers the contrast.
   b. Absorption properties of the fibroglandular, fatty, and pathological tissues nearly equal.
   c. Muscle and fatty tissue absorb equal amounts of low energy photons.
   d. Atomic numbers of fibroglandular, fatty, and pathological tissues are the same.

12. (404) Which of the following mammographic projections requires the highest kVp and why?

   a. Axillary because muscle tissue is involve.
   b. Craniocaudal because the thickness is greatest.
   c. Mediolateral because the thickness is greatest.
   d. Mediolateral because the retromammary space is demonstrated.

13. (405) If you must use a large focal spot for mammography, what action could be taken to improve the detail?

   a. Increase the FFD.
   b. Decrease the FFD.
   c. Reduce the kVp by four.
   d. Use intensifying screens.

14. (406) Why should the breast be positioned so that the nipple is in profile?

   a. It reduces skin folds.
   b. Skin thickening is demonstrated better.
   c. Retraction of the nipple could be a pathological sign.
   d. Many lesions are located immediately posterior to the nipple.

15. (406) Why should the patient be instructed to sit straight and pull her shoulders back for the craniocaudal projection of the breast?

   a. It places the nipple in profile.
   b. It reduces the part film distance.
   c. It demonstrates the tail of the breast.
   d. It eliminates unwanted shadows on the radiographs.

16. (407) Why is it extremely important for you to keep radiation exposure of obstetrical patients to a minimum?

   a. Low energy photons increase the patient's absorbed dose.
   b. The fetus can only tolerate seven roentgens of exposure.
   c. Growing and gonadal tissues are highly suspectible to alteration.
   d. High kVp techniques encourage absorption due to the photoelectric effect.

17. (407) What is the most common cause of excessive radiation exposure to an obstetrical patient and fetus?

   a. High absorbed dose due to high kVp.
   b. High exposures due to part thickness.
   c. Repeat radiographs due to fetal motion.
   d. Repeat radiographs due to improper positioning.

18. (407) Why should you use high-speed screens and films when radiographing obstetrical patients?

    a. They improve the contrast.
    b. They reduce patients' exposure.
    c. They provide greater exposure latitude.
    d. They lend themselves to technique compensation.

19. (408) Why is it important for you to identify early pregnancy signs on a radiograph?

    a. Nurse clinicians are not trained to interpret radiographs.
    b. Physician assistants are not trained to interpret radiographs.
    c. To assist a new obstetrician in detecting pregnancy.
    d. To prevent excessive exposure to the fetus if the physician does not know his patient is pregnant.

20. (409) Which of the following fetographic projections usually provides the best detail and why?

    a. PA because part film distance is reduced.
    b. AP because patients' comfort helps eliminate part motion.
    c. Anterior oblique because the fetal head is seen in profile.
    d. Posterior oblique because the distal femoral epiphyses are projected clear of the spine.

21. (411) What two factors must be given special attention when performing lateral placentography?

    a. FFD and grid radius.
    b. Photon energy and focal spot size.
    c. Size of the placenta and tube filtration.
    d. Density of the placenta and thickness of the abdomen.

22. (412) If a filter that covers half of the primary beam is used for a lateral placentogram, over which portion of the abdomen should it be placed and why?

    a. Anterior to provide even film density.
    b. Posterior to provide even film density.
    c. Anterior because the placenta is usually located there.
    d. Posterior because the placenta is usually located there.

23. (415) Why is the pelvimeter used for the Colcher-Sussman pelvimetry?

    a. It projects the fetal head in actual size.
    b. It prevents distortion of the ischial spines.
    c. It allows the degree of magnification to be determined.
    d. It provides the radiologist with the means to determine the part film distance.

24. (416) If the ruler is not placed parallel with the film during a Colcher-Sussman projection, how, if in any way, are the measurements affected?

    a. They are not affected.
    b. They are higher than normal.
    c. They are lower than normal.
    d. They are higher on the AP and lower on the lateral.

25. (217) Which statement below gives the correct procedure to follow in checking for rotation of the pelvis when positioning a patient for an AP Colcher-Sussman projection?

    a. Measure either the height of the anterior superior iliac spines or that of the greater trochanters, but not both.
    b. Measure only the height of the anterior superior iliac spines to see if they are equidistant from the table.
    c. Make certain that the heights of the anterior superior iliac spines from the table are equal to the heights of the greater trochanters from the table.
    d. Make certain that the measured heights of the anterior superior iliac spines are equidistant from the table, and also that those of the greater trochanters are equidistant from the table.

26. (417) What would result, if anything, if the 14 X 17-inch cassette were centered 4 1/2 inches above the symphysis pubis for an AP Colcher-Sussman projection?

    a. Nothing, this is normal procedure.
    b. The ruler would be too high on the radiograph.
    c. The ruler would be included on the radiograph.
    d. Since the ruler would not be included on the film's lower margin, the magnification of the transverse diameters could not be determined.

27. (418) Which of the following actions is a common error in positioning a patient for a lateral Colcher-Sussman projection?

    a. Placing supportive material between knees and ankles.
    b. Flexion of the femurs to the point that they superimpose the symphysis pubis.
    c. Extending the femurs to adequately visualize the symphysis pubis.
    d. Elevation of the anterior portion of the abdomen with a wedge-shaped sponge.

28. (420) What description listed below is indicative of an elliptical tomographic-tube movement?

    a. Spiral movement.
    b. Linear movement.
    c. Pretzel-like movement.
    d. Movement along an oblong circular path.

29. (421) Why is a particular structure demonstrated on a tomogram with little or no blurring?

    a. It is projected with a good exposure angle.
    b. It is projected by a relatively small focal spot.
    c. It is projected to different locations on the film.
    d. It is projected to the same relative location on the film.

30. (421) Which of the following statements best describes which structures are blurred and/or which structures are sharp on a tomogram?

    a. Structures located in the layer are blurred.
    b. Structures located in the focal plane are sharp.
    c. Structures located in a vertical plane are sharp.
    d. Structures projected by a large exposure angle are blurred.

31. (422) What relationship exists between exposure angle and section thickness?

    a. A large exposure angle produces a thin section.
    b. A small exposure angle produces a thin section.
    c. Exposure angle and section thickness are not related.
    d. A 5-degree change in exposure angle produces a 0.5-mm change in section thickness.

32. (423) Structures A, B, and C are located in the same vertical plane of a body area. Structure B is at the same level as the fulcrum. Structure A is 1 cm farther from the film than structure B. Structure C is 0.5 cm closer to the film than structure B. Which of the listed structures is blurred most on a tomogram if any, and why?

    a. Blurring is equal.
    b. C because the exposure angle is least.
    c. A because the exposure angle is greatest.
    d. B because the exposure angle is greatest.

33. (424) Why is each pair of intensifying screens in a book cassette of a different speed?

    a. Top screens require more exposure.
    b. Beam intensity is reduced by the cassette.
    c. Photon transmission is affected by the inverse square law.
    d. Visualization of different levels require different film densities.

34. (426) Why is the exposure needed for a three-film book cassette greater than one-third of that needed for a single film tomogram taken under the same conditions?

    a. The three films of the book cassette demonstrate deeper structures.
    b. Book cassette exposure is determined by the speed of the top, slow screens.
    c. Book cassette exposure is determined by the speed of the bottom, fast screens.
    d. The book cassette front (bakelite material) is thicker than a conventional cassette.

35. (426) Which of the following statements best describes the detail and contrast of tomograms made in a book cassette?

    a. Detail and contrast are similar on all films.
    b. Detail is poor and contrast is low on the upper films.
    c. Detail is poor and contrast is low on the lower films.
    d. Detail is good and contrast is high on the lower films.

36. (428) What is the tomographic amplitude if the rate is 2 inches per second and the exposure time is 4 seconds?

    a. 2 inches.
    b. 8 inches.
    c. 2°.
    d. 8°.

37. (429) If a linear tomogram is being performed, at what angle should the sternum be positioned with respect to the longitudinal axis of the X-ray table and why?

    a. 90° because of the spine.
    b. 45° because of the ribs.
    c. 30° to 45° because of the spine and ribs.
    d. 25° to 35° because of the spine and ribs.

38. (430) Which of the following tube angles, if any, can be used for stereoscopy?

    a. 6° only.
    b. 3° only.
    c. 3° or 6°.
    d. The tube should not be angled.

39. (431) In what direction should the X-ray tube be shifted for stereoscopic PA chest radiographs and why?

    a. Along the longitudinal axis because lung tissue is radiolucent.
    b. Along the longitudinal axis because the ribs are the predominant lines.
    c. Along the transverse axis because the spine forms the predominant line.
    d. Along the transverse axis because each lung forms a predominant line.

40. (432) Which of the following statements best describes the appearance of the related structures when you correctly view stereoscopic PA radiographs of the chest?

    a. The image appears in three dimensions.
    b. The anterior ribs appear nearer to you than does the sternum.
    c. The heart appears nearer to you than do the posterior ribs.
    d. The anterior ribs appear farther from you than do the posterior ribs.

41. (433) A PA chest radiograph (A) is on a viewbox with the patient's right side on your right side. Another radiograph (B), a left lateral radiograph of the skull, is on another viewbox with the patient's facial bones on your right side and his posterior skull on your left side. Which of the following statements best describes your view of the radiographs?

    a. You are viewing the tube side of both radiographs.
    b. You are viewing the film side of both radiographs.
    c. You are viewing the tube side of radiograph A and the film side of radiograph B.
    d. You are viewing the tube side of radiograph B and the film side of radiograph A.

42. (435) The images of two stereoscopic radiographs are superimposed, and the radiographs are positioned so that the direction of the tube shift is parallel with the floor. The radiograph seen by your right eye during stereoscopic viewing is the one farthest to the

    a. top.
    b. left.
    c. right.
    d. bottom.

43. (436-437) \How do you place the stereoscopic radiographs on the viewboxes with respect to the tube side of the film, before viewing stereoscopic radiographs by both the cross-eyed and single-mirror methods?

    a. Tube side toward you for both methods.
    b. Tube side against the viewbox for both methods.
    c. Cross-eyed-tube side toward you; single-mirror-tube side against viewbox.
    d. Cross-eyed-tube side against viewbox; single-mirror-tube side toward you.

44. (438) What projections should you normally make to aid the physician in localizing a localizing a foreign body in the extremitist?

    a. AP only.
    b. PA only.
    c. Lateral only.
    d. AP or PA and lateral.

45. (439) Which statement below correctly relates to a radiographic procedure used in the single triangulation method of localizing a foreign body in the trunk?

    a. Mark the skin after performing the radiograph.
    b. The depth of the foreign body is measured directly on a fluoroscopic beam.
    c. Basically, the depth is determined because the foreign body appears twice on the radiograph.
    d. Collimate to a large cone field several times larger than the foreign body to correctly mark the skin.

46. (441) What parts of Sweet's localizer are projected onto the radiographs, thereby serving as reference points for localization of a foreign body in the eye?

    a. Ball and cone.
    b. Sighting notches.
    c. Horizontal and vertical arms.
    d. Set screw and trigger release.

47. (442) How many films are used, and how many exposures are made when localizing a foreign body using Sweet's method?

    a. One film and two exposures.
    b. Two films and one exposure.
    c. Two films and two exposures.
    d. One or more films and one or more exposures.

48. (442) As a part of the Sweet's eye localization process, slide the localizer forward until the ball

    a. nearly depresses the open eyelid.
    b. comes within 10 mm of the closed eyelid.
    c. depresses the closed eyelid one thickness.
    d. contacts, but does not depress, the closed eyelid.

49. (444) A scanogram is performed to determine which of the following measurements?

    a. Length of a fracture.
    b. The length of the spine.
    c. Actual and relative lengths of long bones.
    d. The depth of a foreign body and biparietal diameter.

50. (445) When a scanogram is being performed, the X-ray tube is aligned with respect to what portion(s) of the part?

    a. Ends.
    b. Middle.
    c. Lateral borders.
    d. Proximal portion only.

51. (446) What determines the number of exposures made during a scanogram?

    a. Length of the bone.
    b. Number of related joints.
    c. Purpose of the examination.
    d. Degree of magnification necessary.

52. (446) When performing a radiograph to compare the length of the right leg to that of the left, which of the following statements applies?

    a. A Bell-Thompson ruler must be used.
    b. A Bell-Thompson ruler need not be used.
    c. AP and lateral projections must be made.
    d. The patient should be in the supine position.

53. (447) When evaluating a scanogram from a quality control point of view, you can determine whether or not the projected size of a bone is the same as its actual size by

    a. comparing one side with the other.
    b. making an estimate directly from the patient.
    c. evaluating the distortion of the ruler markings.
    d. noting the relationship between the CR and the end of the part.

54. (448) What are the names of the two structures located about the knee joint which act as shock absorbers; and specifically where are they located?

    a. Fibular and tibial collateral ligaments on each side of the knee.
    b. Anterior and posterior cruciate ligaments between the femoral condyles.
    c. Medial and lateral cruciate ligaments in the femoral intercondyler fossa.
    d. Medial and lateral menisci between the femoral condyles and superior articular surfaces of the tibia.

55. (448) Which of the following structures prevent medial/lateral movement of the knee joint?

    a. Collateral ligaments.
    b. Cruciate ligaments.
    c. Ligamentum teres.
    d. Menisci.

56. (449) Why should the knee of a patient receiving an arthrogram be massaged before the radiographs are made?

    a. To prevent discomfort.
    b. To compress the menisci.
    c. To distribute the contrast medium.
    d. To allow the demonstration of air/fluid levels.

57. (449) Why should the ace bandage be removed from the knee of a patient receiving an arthrogram?

    a. To relieve the pressure.
    b. To prevent fluid absorption.
    c. To permit visualization of the quadriceps pouch.
    d. To reduce the contrast between tissue and the contrast medium.

58. (450) Why should you perform an arthrogram quickly?

    a. The contrast medium can be absorbed within 5 minutes.
    b. The contrast medium can be absorbed within 30 minutes.
    c. The patient is in considerable pain due to the various positions of the knee.
    d. The longer the contrast material stays in the joint capsule, the greater the chance of simulated pathology.

59. (451) Which of the following types of mobile X-ray units would offer considerable advantages in a hospital where few power outlets are present?

    a. Standard.
    b. Battery-powered.
    c. High-capacity.
    d. Capacitor-discharge.

60. (452) What action should you take to help prevent an electrical shock to your patient when you perform a mobile bedside radiograph?

    a. Use relatively low kVp.
    b. Maintain at least a 12-inch source-to-skin distance.
    c. Do not establish contact between your mobile unit and the patient's bed.
    d. Do not use a 200-volt power supply if a 110-volt power supply is near enough to be used.

61. (453) Which of the following statements best describes the use in the operating room of a mobile X-ray unit that is not explosion-proof?

    a. It is not used when cyclopropane only is being administered.
    b. It is not used when ether or cyclopropane is being administered.
    c. It may be used if an explosion-proof plug and receptacle are utilized.
    d. It may be used immediately after the use of an explosive agent is discontinued.

62. (453) Whether or not an explosive atmosphere exists in the operating room depends upon the

    a. type of anesthetic or preparation agent in use.
    b. amount of explosive agent administered to the patient.
    c. classification of the operation (open or closed reduction).
    d. type of mobile X-ray unit used to perform the radiographic examination.

63. (453) How should the operator of a mobile X-ray unit be assured that the unit is not explosion-proof?

    a. By checking the manufacturer's instruction book.
    b. By locating a warning statement on the unit that is visible as he energizes the unit.
    c. By checking the power cord for the Underwriters' Laboratories, Inc., seal of approval.
    d. By reading AFM 161-38, Diagnostic X-ray, Therapeutic X-ray and Gamma-Beam Protection for Energies Up to 10 Million Electron Volts.

64. (454) What minimums of the source-to-skin distance (SSD) and lead equivalency of the protective apron should be used when performing mobile radiographs?

    a. SSD—12 inches; lead equivalent—0.25 mm.
    b. SSD—15 inches; lead equivalent—0.50 mm.
    c. SSD—18 inches; lead equivalent—0.75 mm.
    d. SSD—18 inches; lead equivalent—1.00 mm.

65. (455) What action should be taken when a patient receiving oxygen therapy is being radiographed?

    a. The oxygen should be turned off if the patient's condition permits.
    b. The oxygen may be left on if your mobile unit is properly grounded.
    c. The oxygen may be left on if the radiograph to be performed is a chest film.
    d. The oxygen should be turned off, and all preparations should be made in advance.

66. (456) Which of the following bedside chest radiographs should be made of a cardiac patient if his condition is such that only minimal movement is permitted?

    a. AP erect.
    b. PA erect.
    c. AP supine.
    d. AP semierect.

67. (457) Why are special articles of clothing worn into the operating room?

    a. They reduce the introduction of bacteria only.
    b. They prevent the buildup of static electricity only.
    c. They offer a color code for the sterile and nonsterile areas.
    d. They reduce the introduction of bacteria and prevent the buildup of static electricity.

68. (458) Why should the mobile X-ray unit be cleaned before taking it into the operating room?

    a. To prevent contamination of the sterile area.
    b. Only to prevent the buildup of static electricity.
    c. Only to reduce the amount of bacteria taken into the room.
    d. To reduce the amount of bacteria taken into the room and to prevent the buildup of static electricity.

69. (458) Which of the following parts of your mobile unit requires special attention when the unit is cleaned prior to taking it into the operating room and why?

    a. Control panel because dust may cause arcing of the contacts.
    b. Power cord because it gets dirtier than any other part of the unit.
    c. Wheels because they contact a large portion of the operating room floor.
    d. Tube head because it may be positioned directly above the operating site.

70. (460) Why are speed and accuracy on your part important when radiographing a patient undergoing surgery?

    a. You could cause the surgeon to use the wrong sutures.
    b. You could prevent "suture closure" if you take too long.
    c. You may affect the anesthetist's decision as to which type of agent to use.
    d. You may lengthen the amount of time the patient must remain under the influence of the anesthetic.

71. (460) With which of the following operative radiographic examinations should a scout film be made?

    a. Hip nailing.
    b. Open reduction of the knee.
    c. Closed reduction of the tibia.
    d. Closed reduction of the distal humerus.

72. (461) Which of the following statements best describes the phenomenon known as solarization?

    a. Exposure is not logarithmic.
    b. Density is unrelated to exposure.
    c. Increasing exposure increases film density.
    d. Increasing exposure decreases film density.

73. (461) If a radiograph is copied using standard X-ray film, the exact or reverse duplication of the tones depends upon what factor?

    a. The amount of exposure.
    b. The speed of the film.
    c. The type of light source.
    d. The density of the radiograph.

74. (461) How does duplicating film differ from standard X-ray film?

    a. It is already solarized.
    b. It reacts to light.
    c. It produces dark shadows.
    d. It is not available in various sizes.

75. (462) What supplies would you need to convert a conventional cassette into one that can be used to duplicate radiographs?

    a. Two sheets of clear glass.
    b. A sheet of clear glass or plexiglass.
    c. A pair of slow-speed intensifying screens.
    d. A sheet of clear glass, and a pair of light-sensitive intensifying screens.

76. (462) If a duplicate of a radiograph is too dark, how should you alter the exposure on a subsequent duplicate?

    a. Use a larger bulb.
    b. Increase the distance.
    c. Decrease the exposure time.
    d. Increase the exposure time.

77. (463) How does the subtraction process remove unwanted structures from an angiogram?

    a. It lowers the overall density of the structures.
    b. It eliminates the contrast between the structures.
    c. It decreases the densities of the contrast-filled vessels.
    d. It reduces the contrast between the vessels and the background.

78. (463) Which of the following statements best describes the subtraction mask?

    a. It is made from the angiogram.
    b. It cannot be used more than once.
    c. Its tones are reversed from that of the scout film.
    d. It shows the same structures as does the angiogram.

79. (464) How should the subtraction film be placed into the special cassette to produce the mask?

    a. Place the emulsion side against the scout.
    b. Place the glossy side against the angiogram.
    c. Place the emulsion side against the antiogram.
    d. Place the glossy side against the subtraction print.

80. (406) What amount of rotation should be used for the axillary projection of the breast?

    a. 45°.
    b. 1° to 30°.
    c. Until the nipple is in profile.
    d. Until the deltoid muscle contacts the film.

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CDC 90370

RADIOLOGY TECHNICIAN

(AFSC 90370)

Volume 4

Special Procedures

Extension Course Institute
Air University

10-5

PREPARED BY
SCHOOL OF HEALTH CARE SCIENCES, USAF (ATC)
SHEPPARD AIR FORCE BASE, TEXAS

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL
OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES
ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

EXAMINATIONS of the five body systems have historically been referred to as special procedures. As we point out repeatedly in this volume, the exact procedures carried out during these examinations depend a great deal upon your radiologist's preference. That is—each radiologist has his own particular method of performing the examination. This does not imply that some procedures are superior to others. It merely means that each radiologist has his own way to arrive at an accurate diagnosis of a patient's condition. Accordingly, this volume deals mostly with procedures that are general in nature. Hopefully, this information will allow you to adapt quickly to the examination regardless of the circumstances involved.

The five body systems include the digestive, urogenital, respiratory, cardiovascular, and nervous. In each chapter we first discuss the anatomy involved. After that we discuss various aspects of the studies to help you better perform your role as a technician in assisting with these examinations.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to School of Health Care Sciences/MST, Sheppard AFB TX 76311. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

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This volume is valued at 33 hours (11 points).

Material in this volume is technically accurate, adequate, and current as of December 1974.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Contrast Studies of the Digestive System

CONVERSION of food to chemical nutrients, usable by the body, occurs in the digestive system. Consequently, malfunction of any of the system components results in impairment of the digestive process. When the degree of impairment is sufficient, medical and/or surgical intervention is necessary. Generally, the first step in such professional treatment requires radiographic examination of the affected system component. Since you are involved in preparing the equipment for and will assist with such procedures, you must have at least a basic knowledge of the organs in the digestive system, how they function, the materials used to make them radiopaque, the radiographic equipment, and how the equipment is generally used. Therefore, this chapter is a discussion of these factors as they apply to representative parts of the digestive system.

1-1. Anatomy and Physiology of the Digestive System

The digestive system consists of the alimentary tract or canal and the accessory organs of digestion. The alimentary tract is 28 to 32 feet long and consists of the mouth, the pharynx, the esophagus, the stomach, the small bowel, the large bowel, the rectum, and the anus. The accessory digestive organs are the salivary glands, the liver, the gallbladder, and the pancreas. We begin our study of the digestive system with the mouth.

600. Name the structures and the bones comprising the roof of the mouth and point out the role of the posterior roof of the mouth during the swallowing process.

The Mouth. Although the mouth, or oral cavity, is made up of various structures, including the teeth, mandible, cheeks, lips, and tongue, our discussion is primarily directed toward the roof of the mouth and the salivary glands.

Roof of the mouth. The roof of the mouth is formed by the hard and the soft palates. The stationary hard palate, forming the anterior portion of the roof of the mouth, is made up of the maxillae and palatine bones, which are covered by mucous membranes. The hard palate joins posteriorly with the soft palate—a fold of mucous membrane which encloses muscular fibers, vessels, mucous glands, and nerves. The soft palate, normally pendant, elevates during the process of swallowing to separate the nasal cavity and nasopharynx from the oral cavity and oropharynx. (See fig. 1-1.)

Exercises (600):

1. What two structures (other than bones) make up the roof of the mouth?

2. What two pairs of bones comprise the anterior portion of the roof of the mouth?

3. What effect does elevation of the soft palate during the swallowing process have on the nasal and oral cavities and the pharynx?

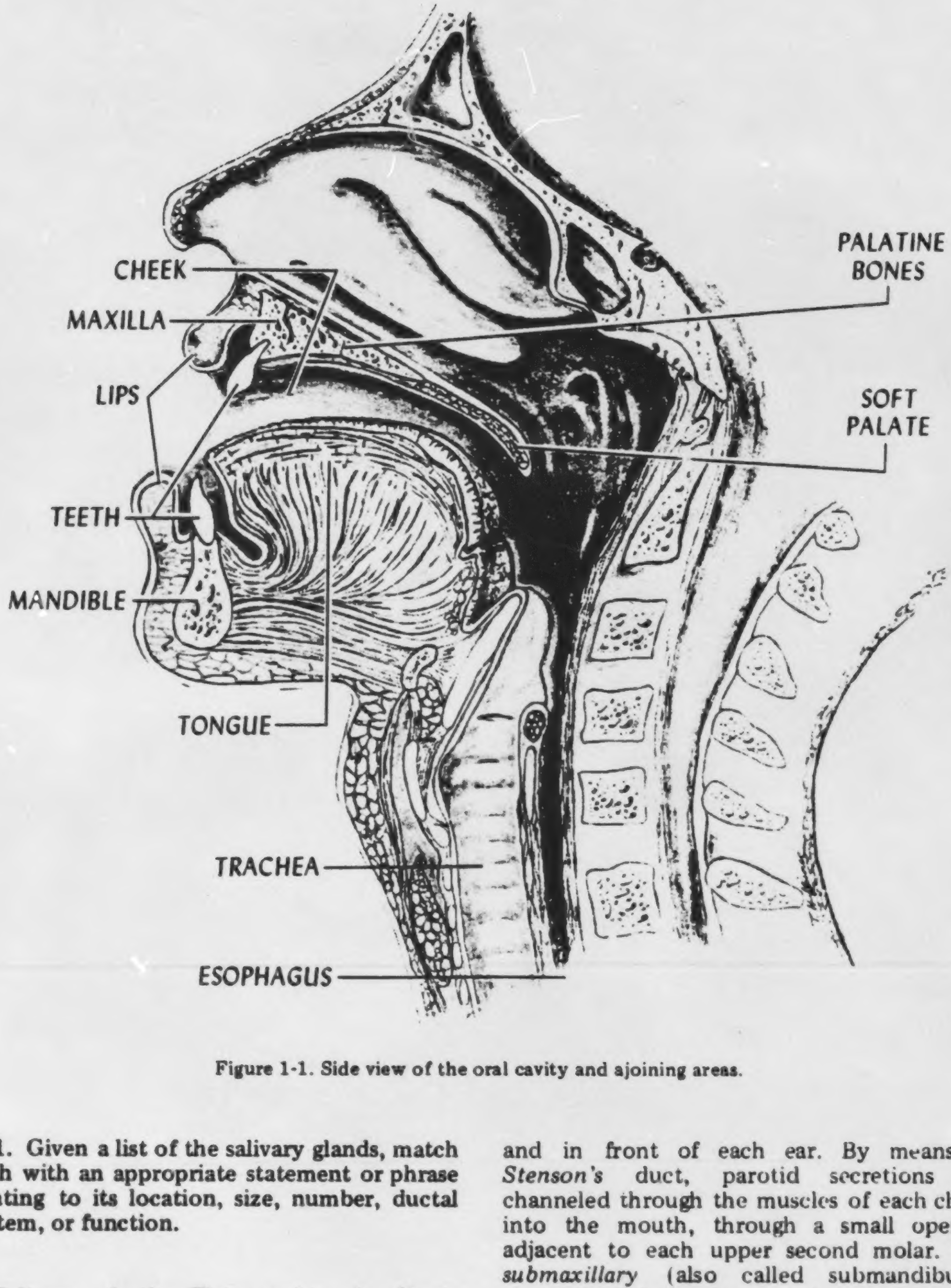


Figure 1-1. Side view of the oral cavity and ajoining areas.

601. Given a list of the salivary glands, match each with an appropriate statement or phrase relating to its location, size, number, ductal system, or function.

Salivary glands. Three pairs of salivary glands are located about the oral cavity. (See fig. 1-2.) They are the parotid, submaxillary, and sublingual glands (see fig. 1-2). Each of these glands secretes saliva into the mouth. The *parotids*, which are the largest of the salivary glands, are located in the superior-posterior aspect of each cheek, below and in front of each ear. By means of *Stenson's* duct, parotid secretions are channeled through the muscles of each cheek into the mouth, through a small opening adjacent to each upper second molar. The *submaxillary* (also called submandibular) glands are located near the anteromedial aspect of each mandibular angle. Submaxillary gland secretions reach the mouth by way of *Wharton's* duct, which opens into the mouth on each side of the frenulum of the tongue. The *sublingual* glands, smallest of the three, are located beneath the mucous membrane of the floor of the mouth immediately on each side of the midline. Saliva from each sublingual gland empties into several small excretory ducts called the ducts of *Rivinus.* Some of the ducts of Rivinus join to form the duct of *Bartholin,* which empties into Wharton's duct. Some empty directly into Wharton's duct, while others empty directly into the mouth on either side of the frenulum of the tongue.

Exercises (601):

Match the salivary gland in column B with the appropriate statement or phrase in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once, or more than once. In addition, more than one column B item may match a single column A entry.

Column A

_ 1. Smallest salivary gland.
_ 2. Empties via Stenson's duct.
_ 3. Located antero-inferior to the ear.
_ 4. Secretes saliva.
_ 5. Communicates with Wharton's duct.
_ 6. Located most inferiorly.
_ 7. Empties into the mouth on either side of the fren-

Column B

a. Submaxillary.
b. Parotid.
c. Sublingual.

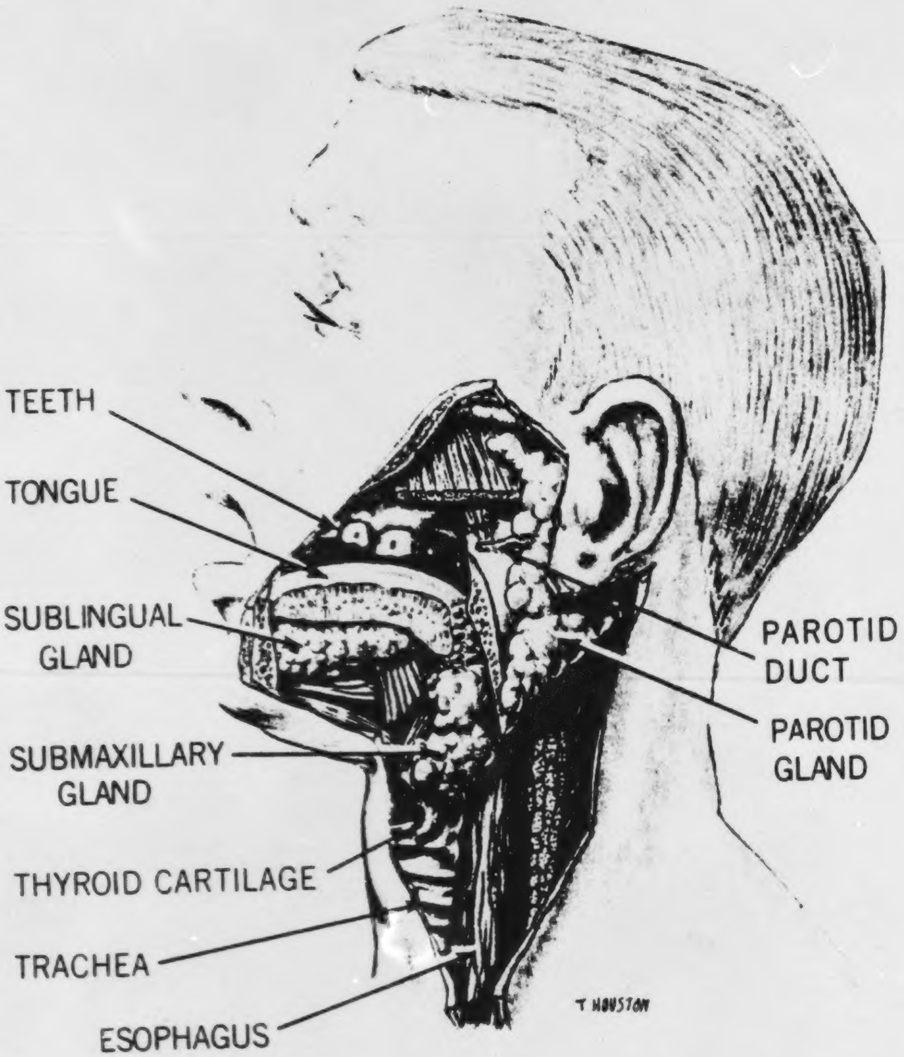


Figure 1-2. Salivary glands and related structures.

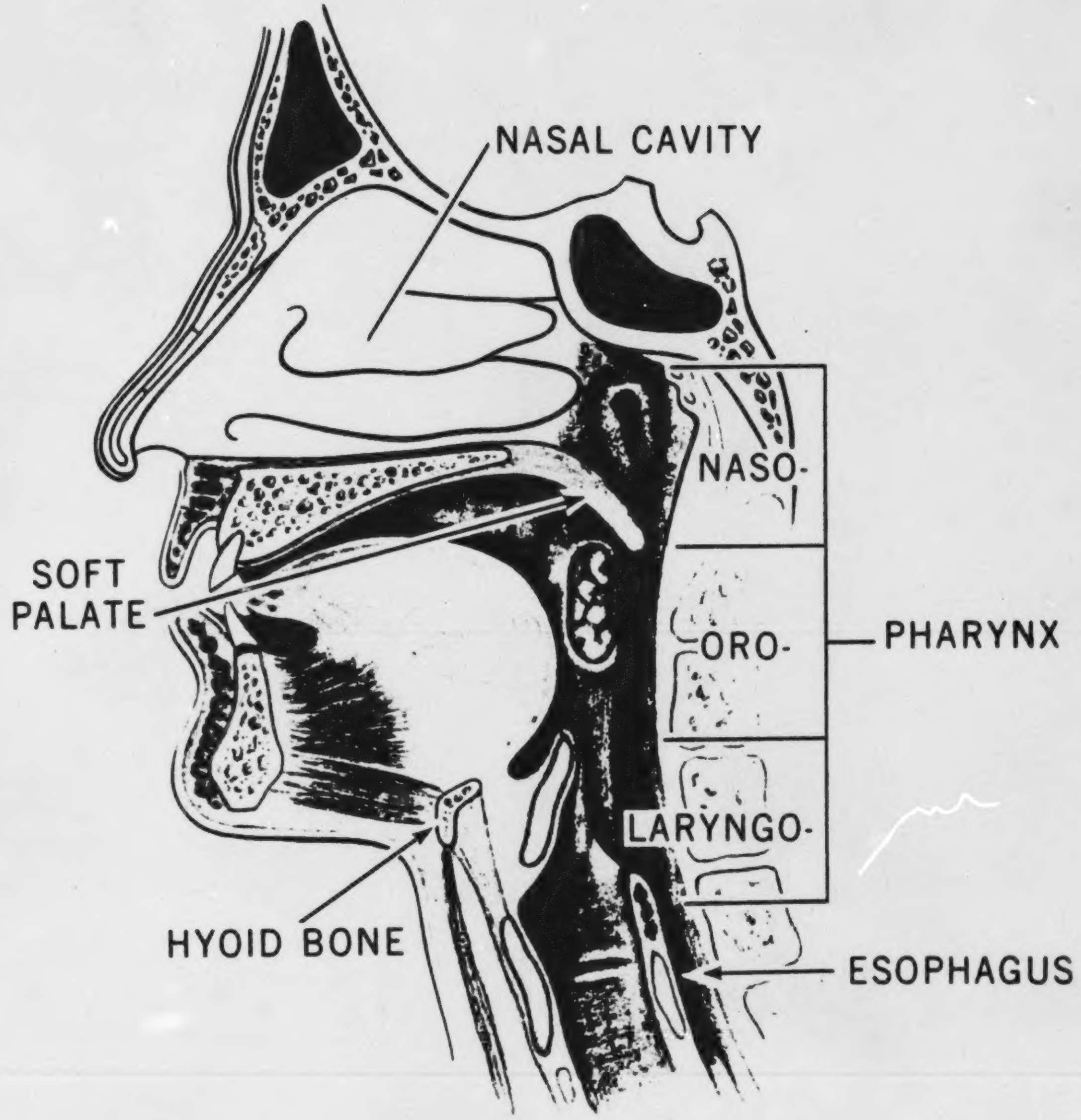


Figure 1-3. The pharynx.

Column A

ulum of the tongue.

_ 8. Empties into the mouth near the upper second molar.

_ 9. Empties via the duct of Bartholin.

_ 10. Empties via the ducts of Rivinus.

_ 11. Located beneath the mucous membrane of the floor of the mouth.

_ 12. Largest salivary gland.

602. Given a list of statements pertaining to the structure, function, and radiographic significance of the pharynx and esophagus, indicate which are true and which are false. If you indicate false, you must explain your answer.

The Pharynx. The *pharynx* is a tubelike structure, approximately 12 cm long, extending from the inferior portion of the skull to the level of the sixth cervical vertebra. (See fig. 1-3.) It is continuous with the nasal cavity anteriorly and the esophagus inferiorly. The pharynx is divided into three parts: (1)

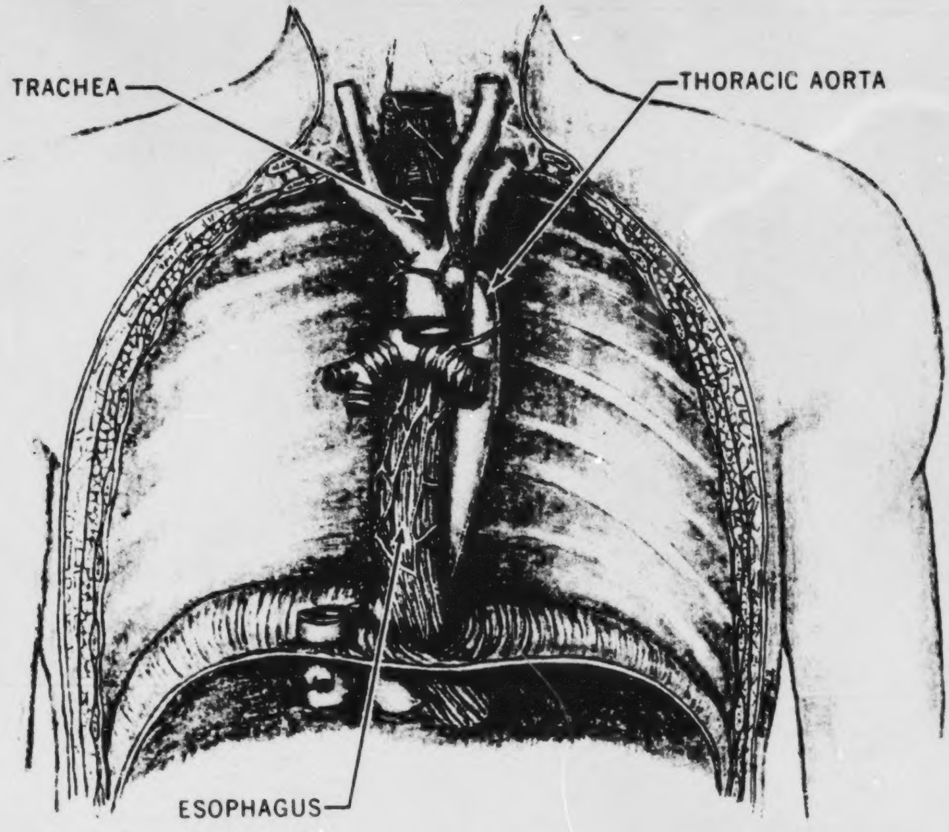


Figure 1-4. Anterior view of the esophagus and related structures.

the *nasopharynx*, (2) the *oropharynx*, and (3) the *laryngopharynx*.

Nasopharynx. The curved nasopharynx is the proximal portion of the pharynx, which serves as an air passage from the nasal cavity to the oropharynx. It extends distally to the inferior margin of the soft palate.

Oropharynx. The oropharynx extends from the soft palate to the hyoid bone. It is common to both the digestive and respiratory systems because it serves as an air passage from the nasopharynx to the larynx and as a food passage from the oral cavity to the laryngopharynx.

Laryngopharynx. The laryngopharynx extends from the oropharynx to the level of the sixth cervical vertebra and the cricoid cartilage, where it becomes the esophagus.

Radiographic considerations. Generally speaking, the nasopharynx and oropharynx can be adequately demonstrated on a soft-tissue lateral projection because they are normally filled with air. The laryngopharynx, however, is usually visualized radiographically after the introduction of a contrast medium because it is not a normal air passage.

The Esophagus. The *esophagus* is the

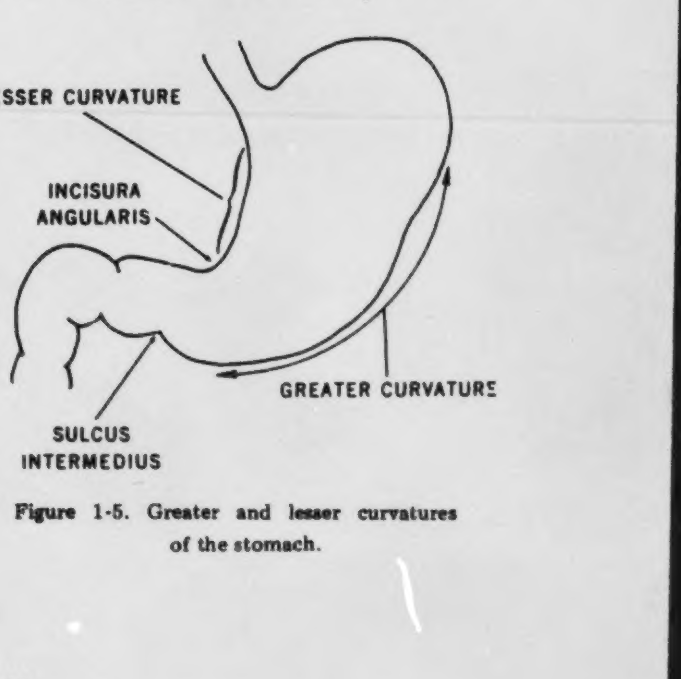


Figure 1-5. Greater and lesser curvatures of the stomach.

portion of the digestive system where peristalsis begins; it connects the pharynx to the stomach. It is approximately 25 cm long and from 10 to 30 mm in diameter. (See fig. 1-4.) As seen from the front, it appears as a "lazy S." It begins in the midline and inclines slightly to the left, back to the right, and then to the left again where it enters the stomach at the level of the eleventh thoracic vertebra. As seen from the side, it follows the curvatures of the lower cervical and thoracic spines. Notice in figure 1-4 that the esophagus is in close proximity to the aorta. The esophagus is also located along the posterior border of the heart. You can see how the location of the esophagus with respect to the aorta and heart can be used to advantage to radiographically demonstrate certain abnormalities of those two structures. If the esophagus is filled with a contrast medium, an enlarged heart or an aortic aneurysm may show a portion of the esophagus displaced from its normal location.

Exercises (602):

Indicate which of the following statements pertaining to the structure and functions of the pharynx and esophagus are true and which are false. If you indicate "false," explain your answer.

T F 1. The pharynx is approximately 12 cm long.

T F 2. The nasopharynx is the middle portion of the pharynx.

T F 3. Food and air passes through the laryngopharynx.

T F 4. The most distal portion of the pharynx is the laryngopharynx.

T F 5. The nasopharynx and oropharynx can be demonstrated on a lateral radiograph because of the presence of air.

T F 6. The laryngopharynx is usually demonstrated on a radiograph after introduction of a contrast medium.

T F 7. The laryngopharynx is continuous with the proximal esophagus.

T F 8. The esophagus is approximately 30 cm long.

T F 9. The esophagus, after beginning in the midline, curves first to the left, back to the right, and back again to the left.

T F 10. The esophagus is located anterior to the heart.

T F 11. Abnormalities of the heart and aorta may displace the normal course of the esophagus.

603. Provide the names or locations of key stomach structures and give the shapes and locations of the stomach according to body habitus.

The Stomach. The stomach is the most dilated portion of the digestive system and extends from the esophagus to the small intestine.

General structure. The stomach has two main borders or *curvatures:* (1) the *greater* curvature, and (2) the *lesser* curvature. (See fig. 1-5.) The greater curvature is the larger of the two and contains a slight groove called the *sulcus intermedius.* The lesser curvature, the smaller, is located on the right side of the stomach and contains a well-defined notch, the *incisura angularis.*

There are two openings in the stomach, as shown in figure 1-6. The proimal opening at the junction of the esophagus is the *cardiac orifice,* which normally lies at the level of the eleventh thoracic vertebra about 1 inch to the

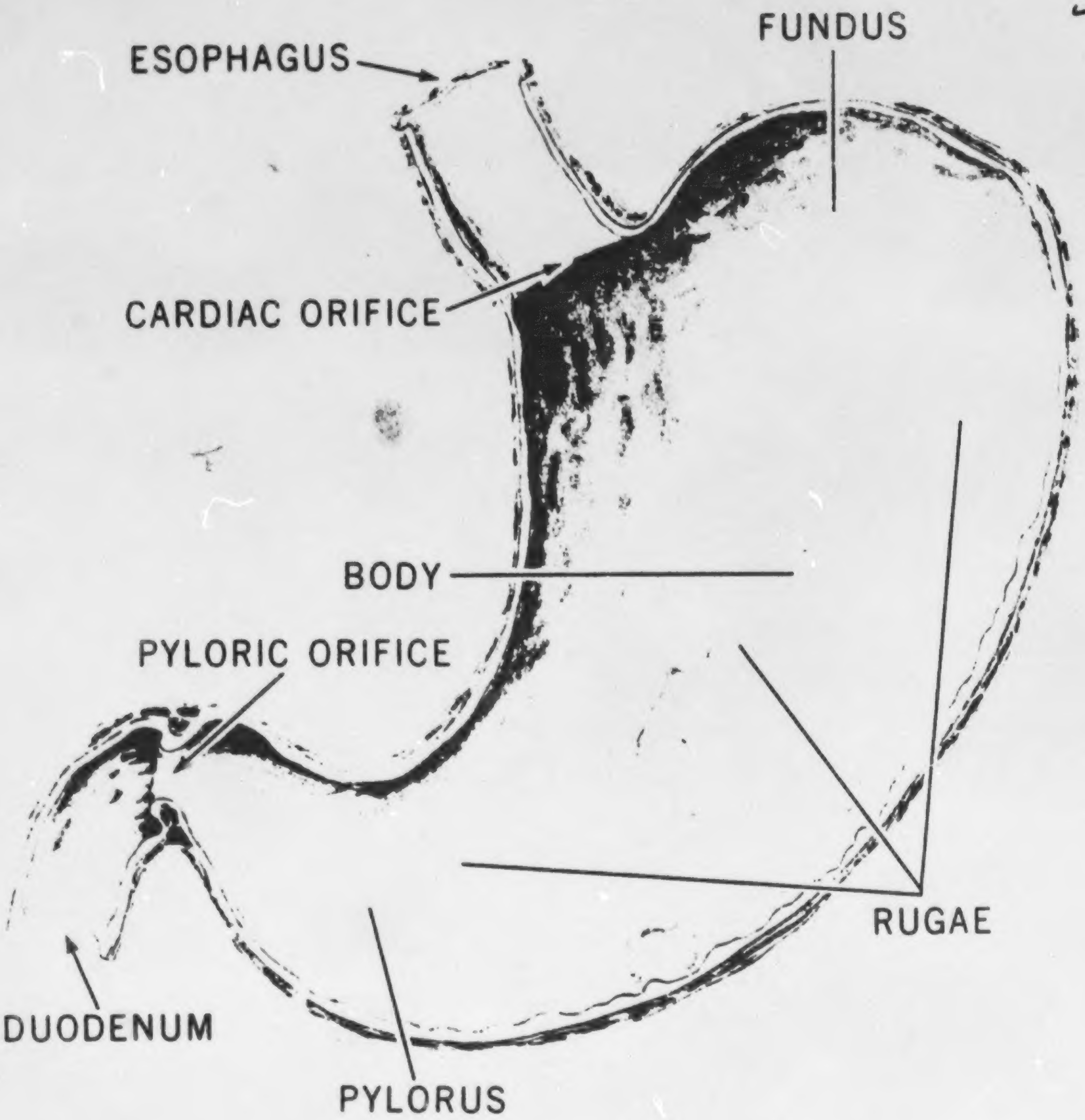


Figure 1-6. The stomach.

left of the lateral sternal border. The lower opening, which communicates with the small intestine, is the *pyloric orifice*. It normally lies about 1 to 2 inches to the right of the midline at the level of the upper border of the first lumbar vertebra.

The stomach proper is divided into three parts: (1) the *fundus*, (2) the *pylorus*, and (3) the *body*. The fundus is the dome-shaped portion lying directly beneath the left hemidiaphragm. It extends inferiorly to a transverse plane passing through the cardiac orifice. The pylorus is the distal portion of the stomach, and the term "body" identifies the remainder. Thick folds, called *rugae*, are located throughout the internal surface of the stomach. The rugae are most prominent when the stomach is empty and tend to flatten out when it is distended. The relationship of the stomach to surrounding abdominal structures can be seen in figure 1-7.

Locations and shapes of the stomach. One of the problems technicians face when radiographing the stomach is to include the entire structure on a 10- x 12-inch film. The problem is due to the various locations of the

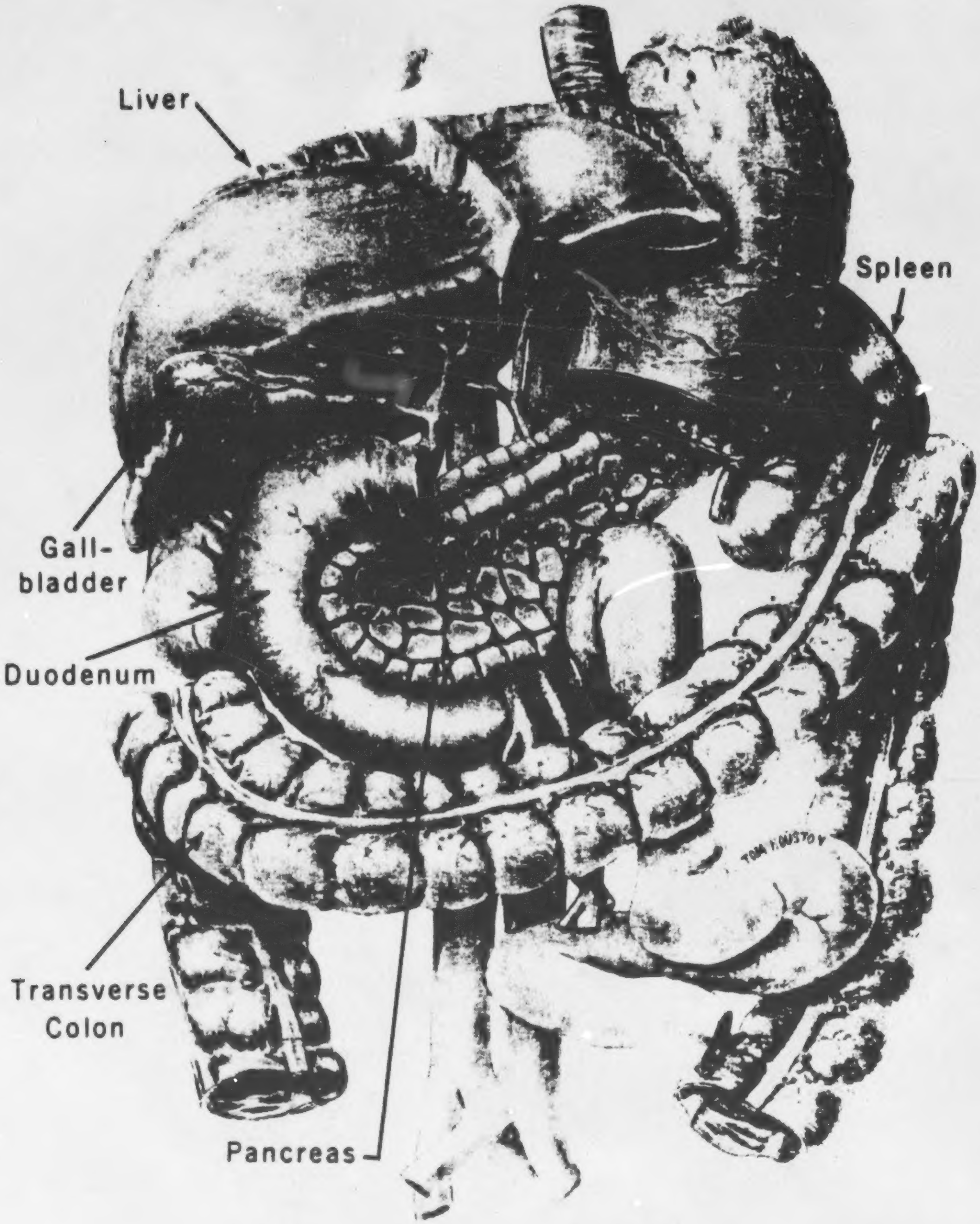
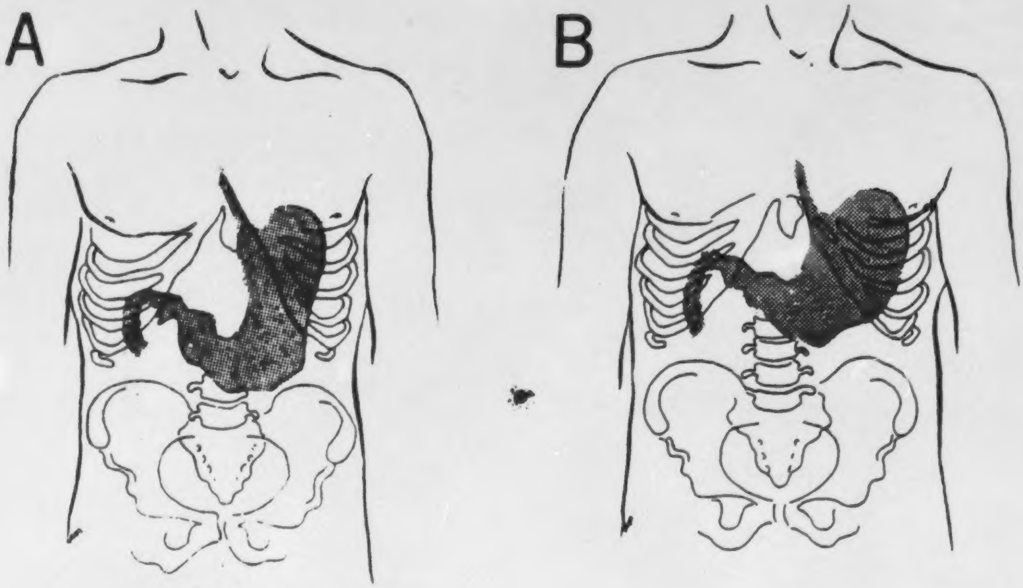


Figure 1-7. Location of the stomach in relation to other abdominal structures.

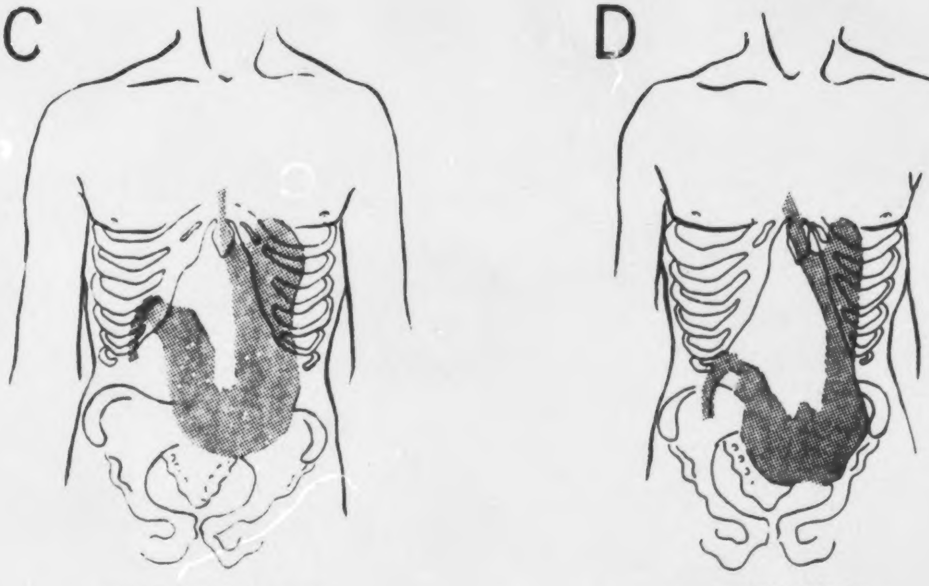
stomach. We cannot teach you precisely where to center your film and patient to consistently "hit" the stomach with a 10- x 12-inch—that comes only with experience. We will, however, review the relative location of the stomach to provide you with the basic information needed to radiograph the stomach. The location and shape of th stomach varies, depending upon the bo habitus of the patient. (See fig. 1-8.)

a. Detail A in the figure shows an individual with the *sthenic* or average build. The esophagus of this individual joins the stomach at the level of the xyphoid process,



STHENIC

HYPERSTHENIC



HYPOSTHENIC

ASTHENIC

Figure 1-8. Variations in stomach location and shape.

while the most inferior portion of the greater curvature is at the level of the iliac crests.

b. The *hypersthenic*, or obese, individual is shown in figure 1-8,B. His stomach is almost horizontally situated and lies highest in the abdomen. Usually, the heavier the individual is—the more horizontal the position of the stomach.

c. The *hyposthenic* (fig. 1-8,C) individual is more slender than the sthenic individual. His stomach is "J-" or "fishhook-shaped" and lies low in the abdomen. The most inferior portion of the greater curvature extends 2 to 4 inches below the level of the iliac crests.

d. The *asthenic* individual is shown in figure 1-8,D. The "J-shaped" stomach is lower in the abdomen than in the hyposthenic individual. This stomach location is normally found in thin elderly patients who have lost their normal muscle tone.

Exercises (603):

1. What stomach curvature is the largest? The smallest?
2. Where is the sulcus intermedius located?
3. What notch is located on the lesser curvature?
4. What are the names and locations of the two stomach openings?
5. Name the three subdivisions of the stomach and indicate which is the proximal, the middle, and the distal portion.

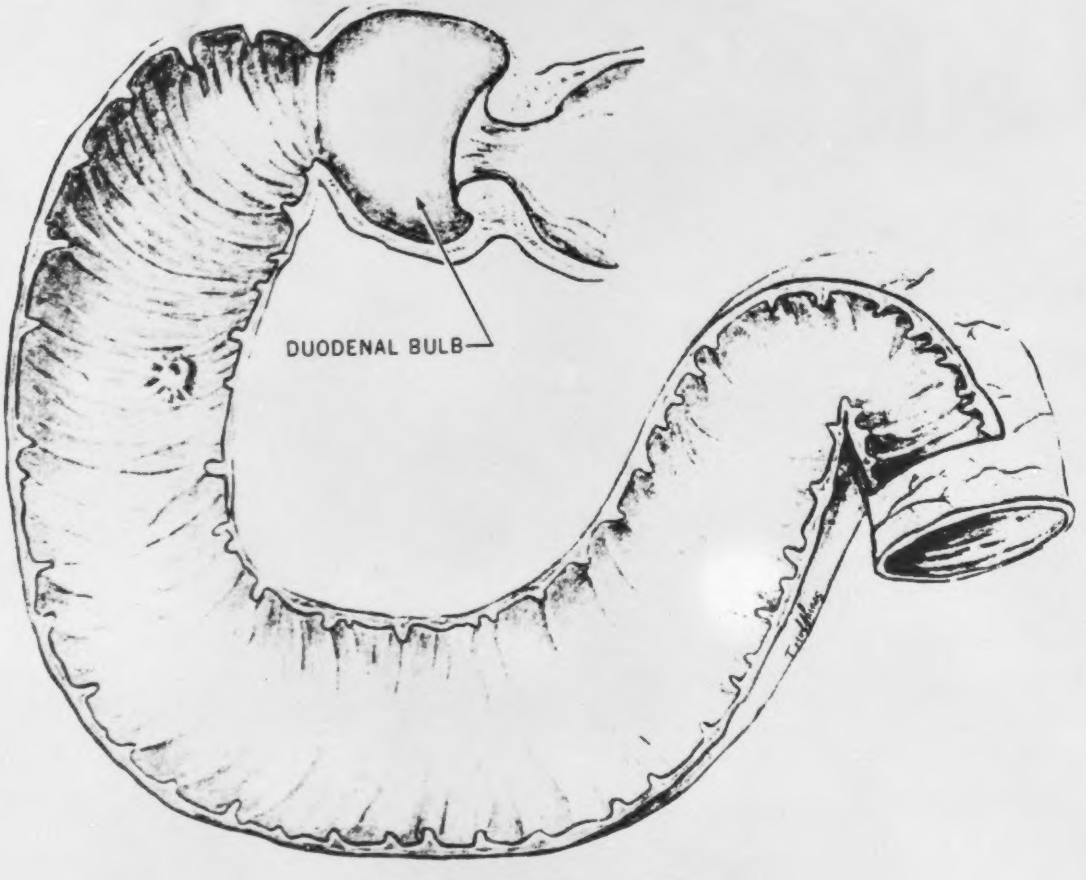


Figure 1-9. The duodenum.

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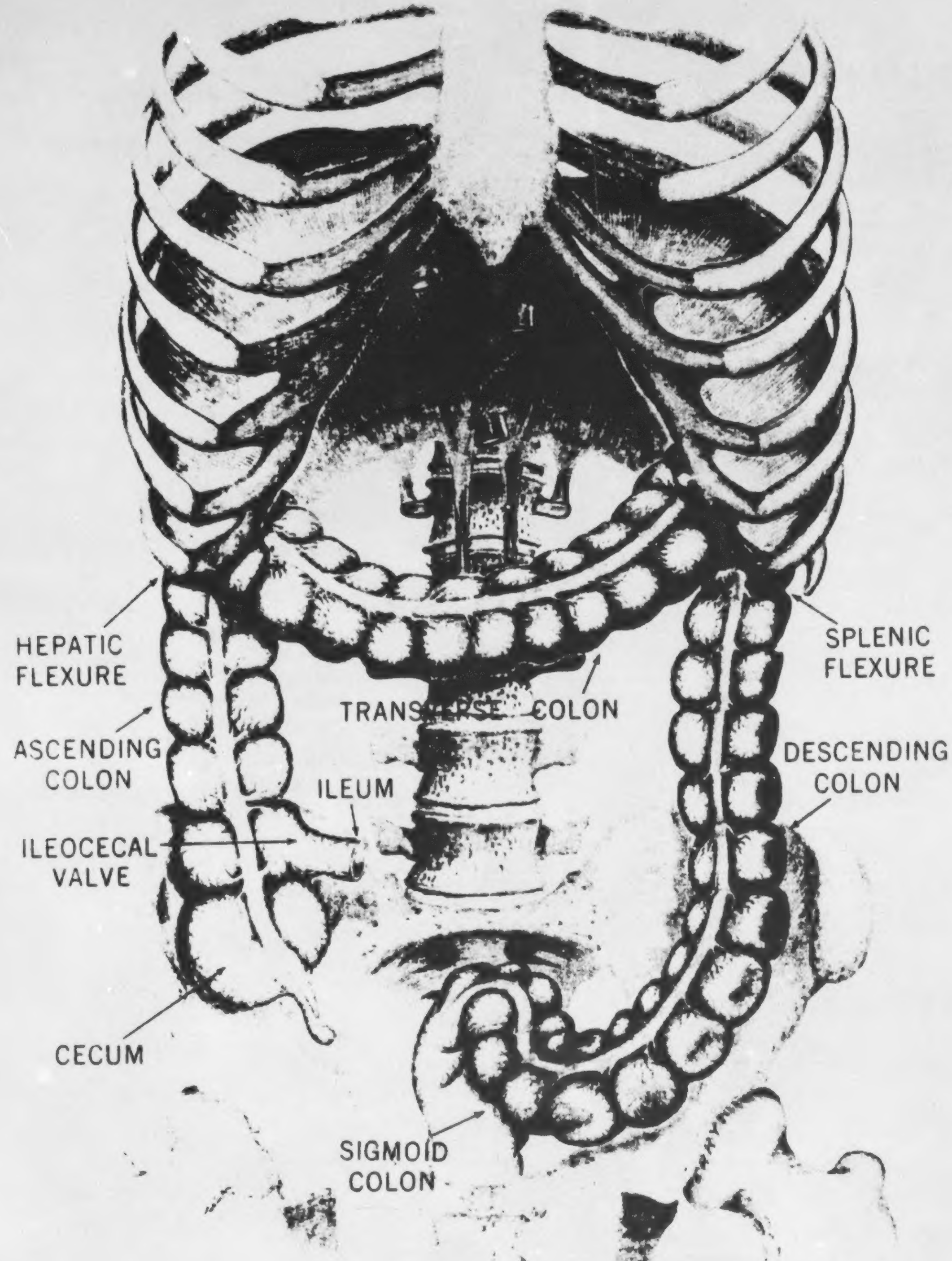

Figure 1-10. The large bowel.

6. To what bony landmark does the lowest portion of the stomach of an individual with an average build extend?

7. In what type of individual is the stomach located highest in the abdomen?

8. In what type of individual is the stomach located lowest in the abdomen?

9. In the hyposthenic individual, where is the most inferior portion of the stomach located?

10. In the hyposthenic or asthenic individual, how is the stomach shaped?

604. Indicate the names, dimensions, and radiographic significance of the major small bowel structures.

The Small Bowel. The small bowel connects the stomach to the large bowel and is divided into three portions: (1) the *duodenum*, (2) the *jejunum*, and (3) the *ileum*.

Duodenum. The proximal portion of the small bowel, the duodenum, shown in figures 1-7 and 1-9, is about 25 cm long. It is the widest segment of the small bowel. The first part of the duodenum, the *duodenal bulb*, normally extends posterolaterally from the pylorus—thus oblique projections are required to view the bulb in profile. Occasionally, it lies in an anteroposterior direction which requires a lateral (left) for profile demonstration.

From the bulb, the duodenum curves downward, descending over the head of the pancreas, then curves medially and upward behind the stomach and finally curves sharply downward. Part of its course roughly resembles a "C," thus the proximal half of the duodenum is sometimes referred to as the "C-loop."

Jejunum. The duodenum joins the *jejunum* over the left margin of the second lumbar vertebra. The jejumum, approximately 7 to 8 feet long, follows a random course.

Ileum. The third portion of the small bowel, the *ileum*, is abot 16 feet long and terminates at the *ileocecal valve*, which connects the ileum to the large bowel. The ileocecal valve, shown in figure 1-10, is especially significant to you because when visualized on a small bowel series, it marks the completion of the series.

Exercises (604):

1. What are the names and approximate lengths of the three parts of the small bowel?

2. What projection is normally required to view the duodenal bulb in profile?

3. When does a lateral projection show a profile view of the duodenal bulb?

4. What is the radiographic significance of the ileocecal valve?

5. What section of the small bowel follows a definite course? Describe its course.

6. What is the "C-loop"?

605. Beginning at the proximal end, name each portion of the large bowel in the order of appearance.

The Large Bowel. The large bowel or *colon* is roughly horseshoe-shaped and extends from the ileocecal valve to the anus. (See figs. 1-10 and 1-11.) The proximal portion of the large bowel is the *cecum*, which is located below the ileocecal valve. The cecum is about 7 cm long, about 7.5 cm in diameter, and terminates in the appendix.

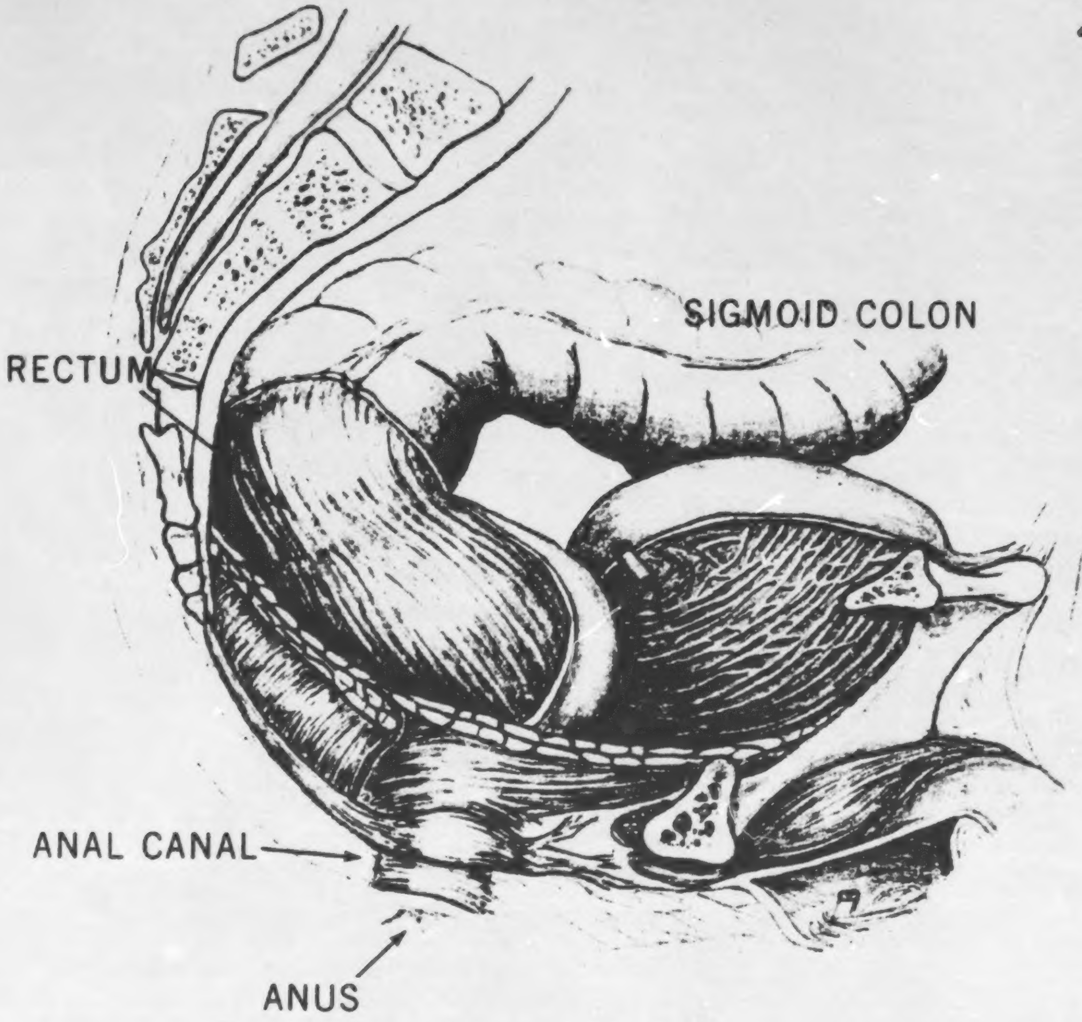

Figure 1-11. The rectum and anus.

Ascending colon. The *ascending* colon is that portion of the colon above the level of the ileocecal valve. It extends upward from the junction of the ileum and cecum, along the right side of the abdomen, and to the inferior surface of the liver. At this point it curves forward and medially to form the *hepatic* flexure.

Transverse colon. The *transverse* colon extends across the abdomen from the hepatic flexure to the spleen. It passes over the descending segment of the duodenum, the pancreas, and the inferior margin of the stomach. At the level of the spleen it curves forward and inferiorly to form the *splenic* flexure.

Descending colon. The *descending* colon extends downward from the splenic flexure to the iliac fossa. From this point, it usually follows the inferomedial curvature of the ileum and joins with the *sigmoid* colon.

Sigmoid colon. The sigmoid colon is "S-shaped," and dips into the pelvis, curving gently downward and toward the midline. Then it curves sharply upward and is slightly inclined toward the sacrum. At about the level of the first sacral segment it curves posteriorly and joins with the *rectum.*

Rectum and anus. The rectum extends downward, lies between the bladder and the coccyx, and joins with the *anal canal,* which terminates in the *anus.*

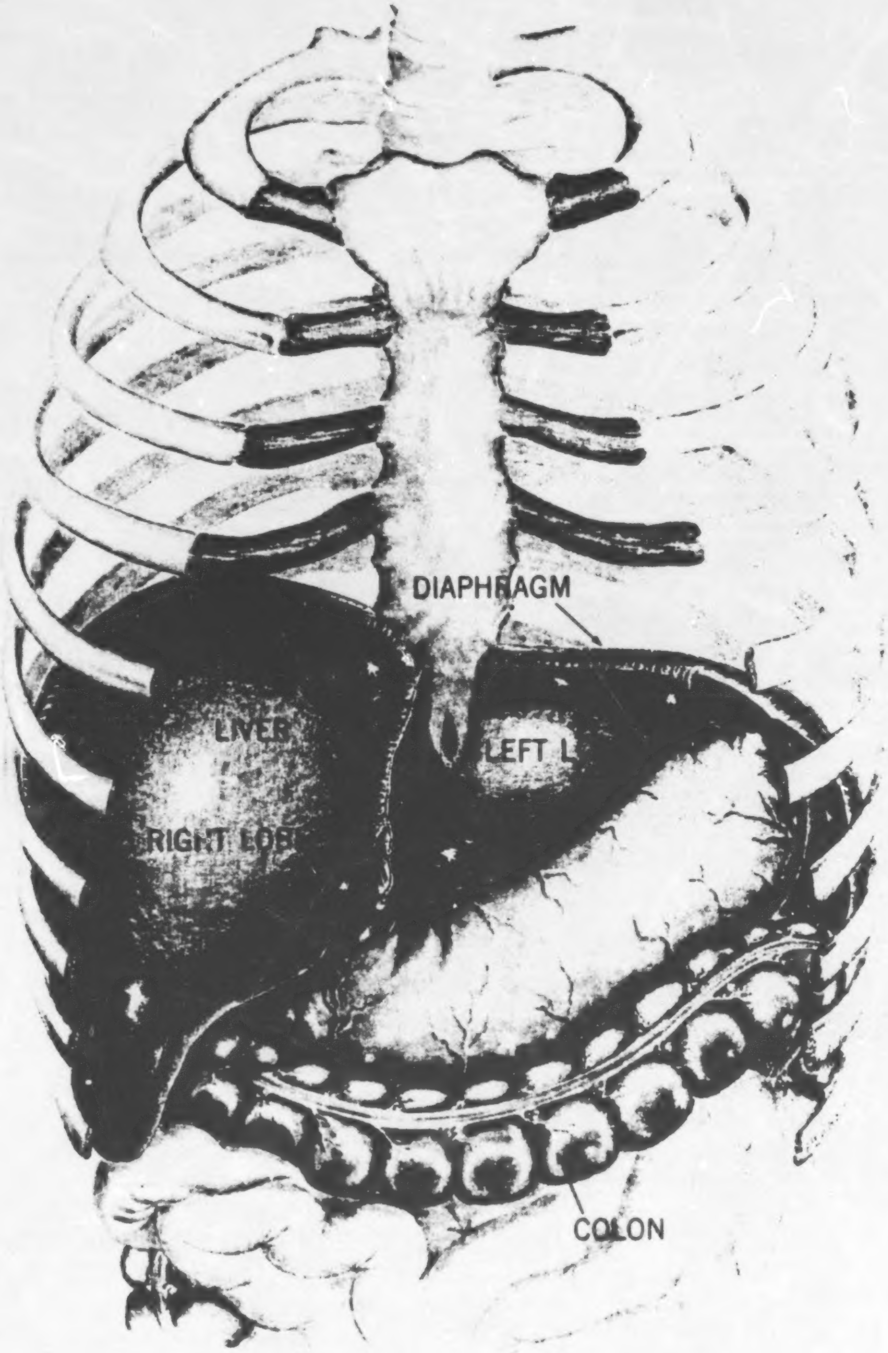

Figure 1-12. The liver.

Exercise (605):

1. Name each portion of the large bowel in order, from the most proximal to the most distal portion.

606. Name and locate major structures of the liver, gallbladder and biliary system, and pancreas.

The Liver. The *liver* lies directly under the right hemidiaphragm. (See fig. 1-12.) It is

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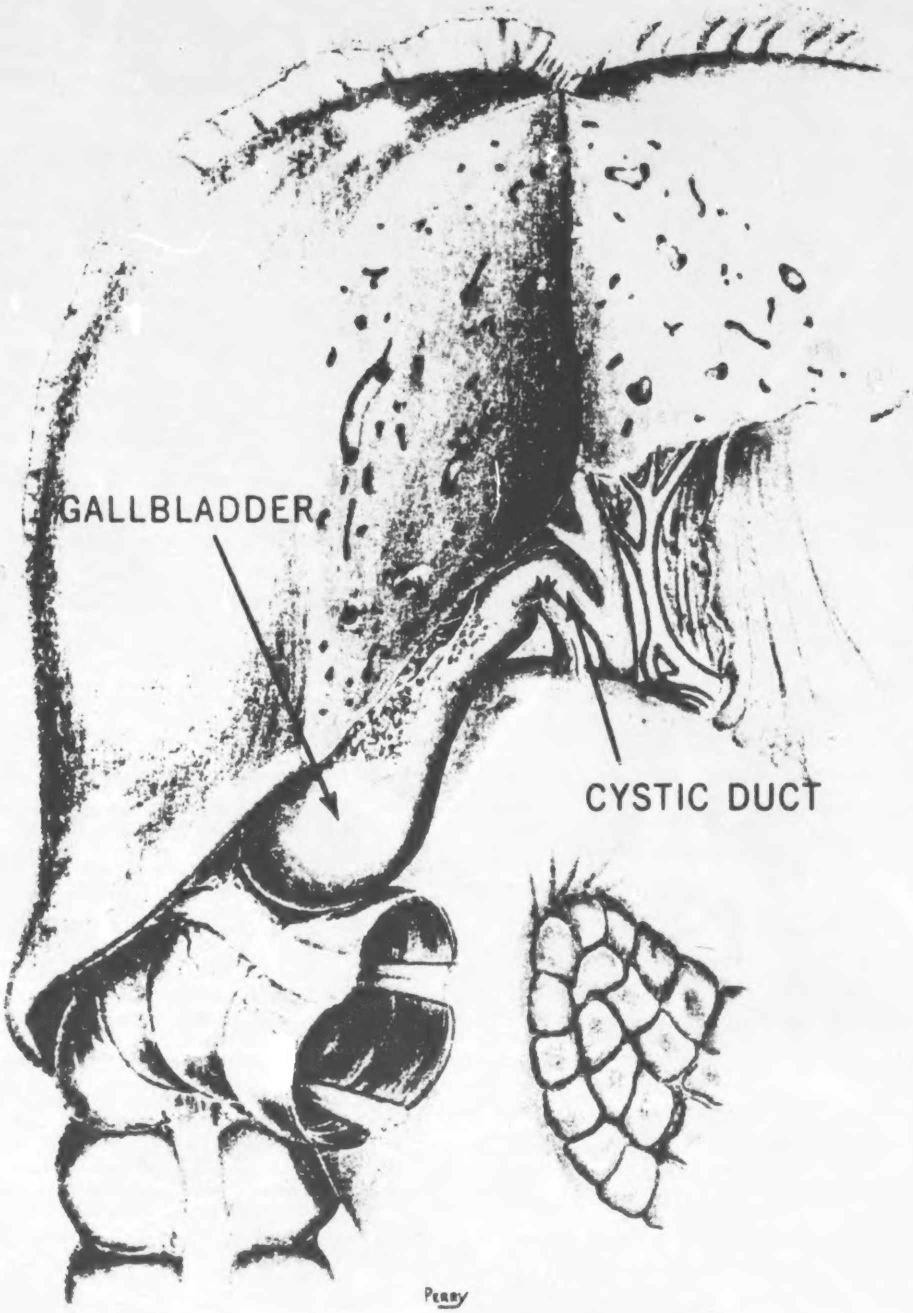

Figure 1-13. The gallbladder.

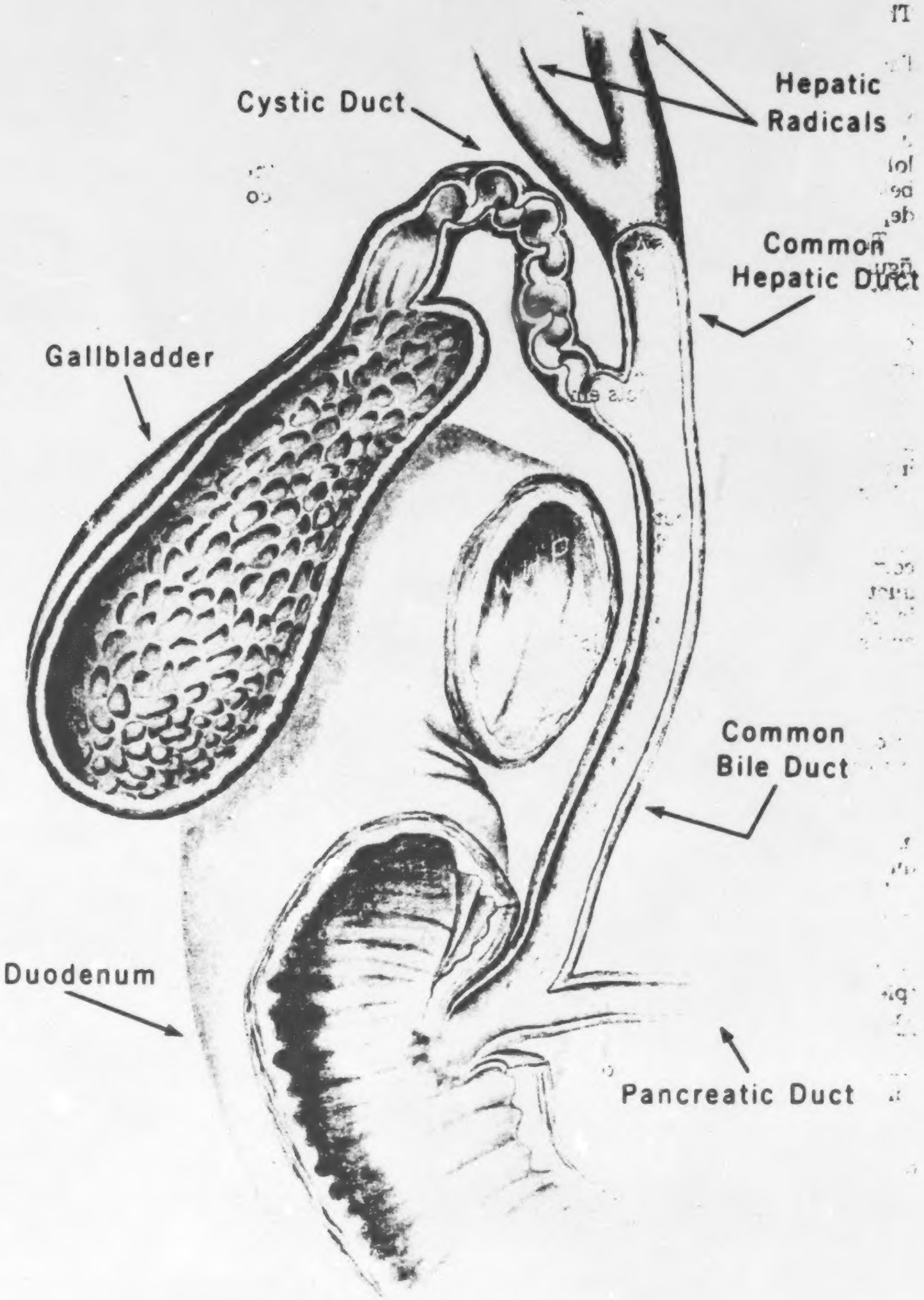

Figure 1-14. The biliary ductal system.

divided into left and right lobes, as seen in the figure. The larger right lobe houses the smaller right lobe proper, plus the *quadrate* and *caudate* lobes located on its inferior surface. The left lobe is small, wedgeshaped and is separated from the right lobe by the falciform ligament.

The Gallbladder and Biliary System. The *gallbladder* (see fig. 1-13) is situated on the inferior surface of the right and quadrate lobes of the liver. It is usually located between the ninth rib and the iliac crest, depending upon the patient's body habitus.

The biliary-ductal system, illustrated in figure 1-14, is made up of the bile ducts found in the liver (caled the *intrahepatic radicals*), the *right* and *left hepatic* ducts, the *common hepatic* duct, the *cystic* duct, the *common bile* duct, and the *duodenal papilla*. The small intrahepatic ducts emanate from all lobules of the liver. They pass downward and inward following the blood vessels and empty into the larger right and left hepatic ducts. These larger ducts join to form the common hepatic duct. This duct descends to join the cystic duct from the gallbladder. The combined ducts then form the common bile duct. The common bile duct is about 10 cm in length. It descends on a slightly lateral course where it usually joins with the *pancreatic duct* to empty into the posterior wall of the duodenum through a common orifice at the *duodenal papilla*, a protrusion into the duodenal lumen. The pancreatic and the common bile ducts occasionally enter the duodenum separately. A sphincter muscle, the *sphincter of Oddi*, normally prevents reflux into the common bile and the pancreatic ducts.

The Pancreas. The pancreas extends from the spleen across the abdomen to the "C-loop" of the duodenum. (See fig. 1-7.) It is comprised of a tail which lies against the spleen, a long, flat body, and an irregularly shaped head which lies against the "C-loop." The pancreatic duct extends from the tail through the midportion of the pancreas, through the head to the duodenum. The *islets of Langerhans* are scattered throughout the pancreas and produce insulin. The pancreatic duct often bifurcates in the region of the head of the pancreas and gives rise to an accessory pancreatic duct, or *duct of Santorini*, which empties into the duodenum about 2.5 cm above the duodenal papilla.

Exercises (606):

In the following exercises fill in the blanks with one or two words, as appropriate.

1. The liver lies directly under the right ______________.
2. The large right lobe of the liver is comprised of the _______, _______, and ________ lobes.
3. The left and right lobes of the liver are separated by the ______________.
4. The gallbladder is located on the ________ surface of the liver.
5. The right and left hepatic ducts unite to form the __________ duct.
6. The common bile duct empties into the _ _____ wall of the _________.
7. The small bile ducts distributed throughout the liver are called the _______ __________.
8. The bile duct leading from the gallbladder is called the __________duct.
9. The ___________ and ____________ ducts usually join to empty by way of a common orifice.
10. The sphincter of Oddi prevents reflux into the ____________ and ____________ducts.
11. A protrusion inside the duodenal lumen where the two main ducts empty is called the _____________.
12. The three major portions of the pancreas are the________, _____________, and _______________.
13. Insulin is produced in the pancreas by the __________ of _____________.
14. An accessory pancreatic duct emptying into the duodenum is called the __________ of ______________.

1-2. Fluoroscopic Fundamentals

Although fluoroscopy is indeed used for examinations other than of the digestive system, we discuss the procedure in this chapter. Basically, we point out some of the principles involved in image intensification,

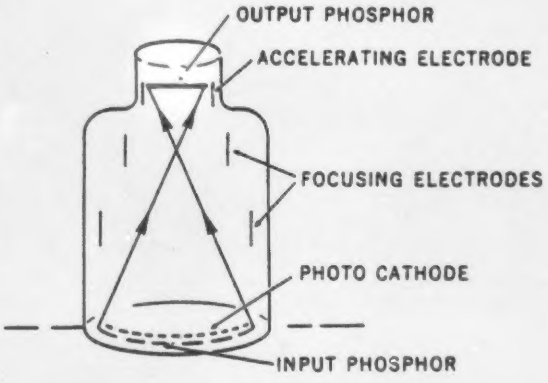

Figure 1-15. An image tube.

cine, television, and videotape recording. Let us begin with a look at the principles involved in image intensification.

607. Give the purpose and explain the basic operation of an image tube.

Image Intensification. Image intensification, as you know, intensifies or amplifies the brightness of a fluoroscopic image. The basic component is the image intensifier or image tube. The tube is a large electron vacuum tube which contains an *input phosphor, photocathode, accelerating* and *focusing* electrodes, and an *output phosphor*, as shown in figure 1-15. Generally, the operation of the image tube is as follows: X-ray photons strike the input phosphor, causing it to emit light photons. The light photons strike the photocathode and cause it to emit photoelectrons. A potential difference between the photocathode and accelerating electrode propels the electrons toward the opposite end of the tube. The electrons, focused by the focusing electrodes, strike the output phosphor and are converted back to light photons. Thus, the fluoroscopic image is converted from X-ray photons to light photons to electrons and back to light photons.

Exercises (607):

1. What is the purpose of the image tube?

2. In your own words explain the basic operation of an image tube.

608. Relate minification gain and flux gain to fluoroscopic image brightness; given appropriate data, determine the brightness gain of an image tube.

Gain in image brightness. As we mentioned before, the image tube increases the brightness of the fluoroscopic image. The amount of increase (brightness gain) is determined by multiplying the *minification* gain by the *flux* gain.

Minification gain is realized by the reduction in the size of the image from the input phosphor to the output phosphor. Minification is easy to understand if you imagine the image displayed by the input phosphor being reduced to the size of the output phosphor, but yet containing the same total amount of light—consequently, the brightness of the image is increased because the light is more concentrated.

Since the sizes of the input and output phosphors are responsible for minification, it follows that the amount of gain is determined by the ratio of the size of the input phosphor to that of the output phosphor. The formula for determining minification gain is:

$$\text{Minification gain} = \frac{(d_1)^2}{(d_2)^2}$$

Where d_1 = diameter of input phosphor, d_2 = diameter of output phosphor. For example: if the diameter of the input phosphor is 7 inches and the diameter of the output phosphor is 2 inches, the brightness of the fluoroscopic image is increased 12.25 times because

$$\begin{aligned}\text{Minification gain} &= \frac{7^2}{2^2}\\ &= \frac{49}{4}\\ &= 12.25\end{aligned}$$

Flux gain in an image tube is caused by increasing the energies of the electrons across the tube. The greater the electron energy as it strikes the output phosphor, the more light photons emitted—consequently, the greater the increase in image brightness. High voltage applied to the accelerating electrode (up to 30 kVp) accelerates the electrons sufficiently to provide an increase in brightness of 35 to 50 times.

Exercises (608):

1. Explain how minification increases the brightness of the fluoroscopic image.

2. Explain how flux gain increases the brightness of the fluoroscopic image.

3. What is the brightness gain of an image tube if the diameters of the input and

output phosphors are 8 and 1 inches, respectively, and the flux gain is 40?

609. Compare the resolution realized from image tube fluoroscopy to that from conventional fluoroscopy.

Resolution. Resolution of a system is usually measured in *line pairs* per millimeter. A line pair is a single line and a space the width of the line. If an image tube has the capability of resolving 2 line pairs, it has greater resolving power than another that resolves one line pair. In actuality, most image tubes do resolve about 2 line pairs, which is slightly less than the resolving power of a conventional fluoroscopic screen. So, on the surface it would seem that some resolution is sacrificed when an image tube is used. However, to fully understand the effective resolving power of an image tube, we need to examine the brightness of fluoroscopic images more closely.

When you look at a conventional fluoroscopic image, which is dark when compared to an intensified image, your eyes perceive the image mostly through the *rods* located on the retina. Viewing with the rods alone is called *scotopic* vision. Rods are very sensitive to light but do not have the capability to perceive fine detail. On the other hand, when you view an intensified image, the light is sufficient to stimulate your *cones*, also located on the retina. Cone vision is called *photopic* vision. An interesting characteristic of the cones is that they allow you to resolve fine detail. Consequently, the effective resolving power of an image tube is high because you use your detail-resolving cone vision.

Exercises (609):

1. How many line pairs do most image tubes resolve without regard to image brightness?

2. Which fluoroscopic system resolves the most line pairs without regard to image brightness?

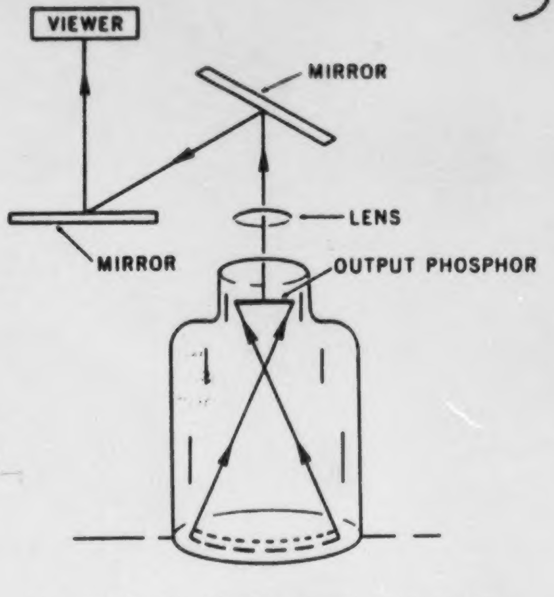

Figure 1-16. Simplified image tube optical system.

3. **Why do you not perceive fine detail when examining a conventional fluoroscopic image?**

4. **Why do you perceive fine detail when examining an image tube fluoroscopic image?**

610. Specify the purpose and limitations of an image tube optical system.

Optical system. **Since the image on the output phosphor of the image tube is too small to be of value, it must be enlarged and presented to the viewer by means of an optical system, also called a periscope. A simplified optical system is shown in figure 1-16. Usually, it consists of a complex system of lens and mirrors.**

Because of the complex arrangement of the optical system, the position of the viewer's eyes is critical in that you can only see the fluoroscopic image from a specific area. If you move your head a few degrees in either direction, you lose the image. Viewing the image is usually limited to one person although a consultation mirror can be

obtained for most image tubes, which allows a second person to view the image. When such a mirror is used, the second observer's position is equally as critical as that of the first.

Exercises (610):

1. What is the purpose of the image tube optical system?

2. What is the maximum number of viewers permitted with an image tube optical system?

3. Briefly discuss the position of the viewer's head when he is using an image tube.

611. Answer key questions pertaining to the field sizes and resolution of image tubes.

Image tube rating. Image tubes are rated according to the diameter of the input phosphor—which usually ranges from 5 to 9 inches. The significance of the rating is the size of the body area viewed through the tube. A 9-inch tube is normally used when large body areas are fluoroscoped. If small areas are normally fluoroscoped, a small tube is usually used because it has better resolution. This increase in resolution over a large diameter image tube is largely due to distortion of the image at the periphery. The distortion is caused by the divergence of the electrons as they approach the output phosphor, and the farther from the center of the output phosphor, the greater the distortion. Consequently, there is more distortion or detail loss on a large tube.

Some image intensifiers, called *dual field*

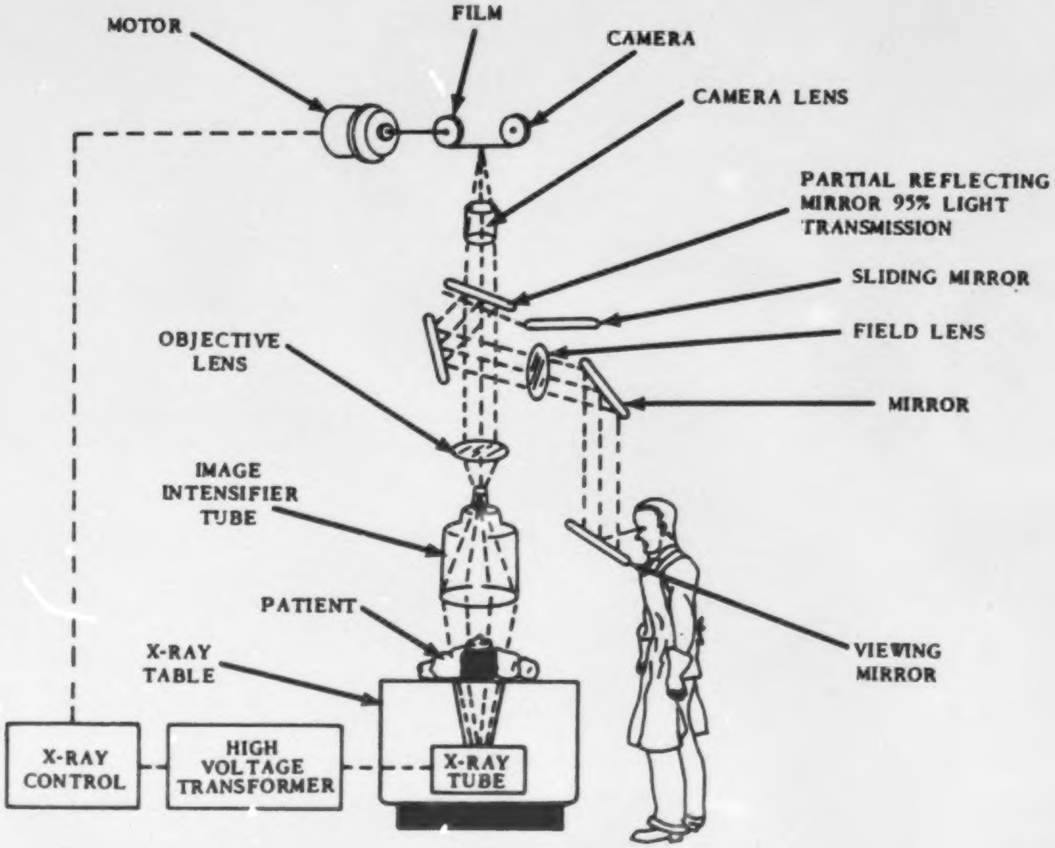

Figure 1-17. Image tube-cine system.

tubes, can be operated in two modes—for example, a 6-inch or 9-inch mode. The mode can be changed quickly by the fluoroscopist to accommodate the examination.

A particular tube size, 6-inch for example, does not mean that the fluoroscopic image will reveal an anatomical area 6 inches in diameter. Keep in mind that the image is slightly magnified when displayed on the input phosphor due to the divergence of the primary beam. Therefore, an image tube shows an area slightly smaller than its rating.

Exercises (611):

1. If an image tube is rated at 7 inches, to what specifically does the 7 inches refer?

2. What is the difference between the resolution of a 6-inch image tube from that of a 9-inch tube? Explain.

3. What is a dual field image tube?

4. Why is the maximum body area demonstrated by an 8-inch image tube slightly less than 8 inches in actual diameter?

612. Give the background and general operating procedures involved in cinefluorography.

Cine. *Cine* or *cinefluorography* can be described simply as the process of recording motion pictures or movies of the fluoroscopic image. Although cine was used experimentally before the image tube was introduced, its applications were severely limited because of the tremendous amount of radiation necessary to produce a fluoroscopic image bright enough for recording. The radiation dose to the patient was considered to be excessive. With the arrival of the image tube, the fluoroscopic image could easily be recorded with a low radiation dose to the patient.

Generally speaking, the cine camera is attached to the image-tube housing so that the camera lens picks up the fluoroscopic image from the output phosphor. In actuality, a highly complex system of lens and mirrors is interposed between the output phosphor and cine film. There is one part of the system that we would like to mention—the *beam splitter*. The beam splitter is a special mirror common to both the direct optical viewing system and the cine recording system. (See fig. 1-17.) It is designed to reflect about 5 to 10 percent of the light to the viewer and transmit 90 percent to 95 percent of the light to the cine camera. The small percentage of light may seem insufficient to allow the fluoroscopic image to be viewed through the periscope. However, because the amount of radiation needed for cine recording is about 10 times that needed for image tube fluoroscopy without cine, the increased radiation brightens the image sufficiently.

In figure 1-17, the partial reflecting mirror (beam splitter) is blocked by the fully reflective sliding mirror when cine is not required, reflecting the entire light beam to the viewer.

Exercises (612):

1. Why was cine originally used sparingly?

2. What event alleviated the problem faced with early cine?

3. Describe the beam splitter and its significance.

4. Why is the very small percentage of light reflected to the viewer sufficient for viewing during cine?

613. Given a list of statements pertaining to the operation of a cine camera, indicate which are true and which are false.

Cine camera. Although a cinefluorographic camera is similar to a regular motion picture

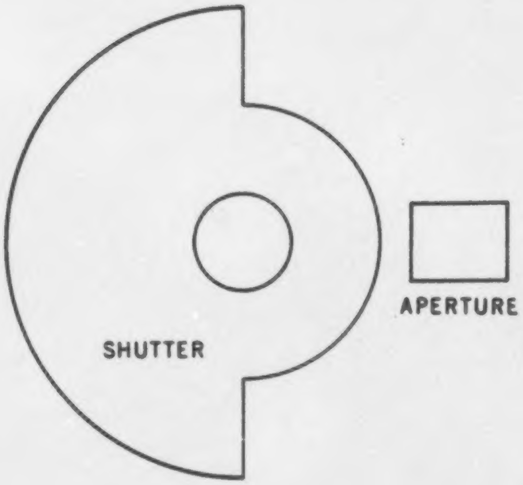

Figure 1-18. Cine camera aperture and shutter.

camera, manufacturers have designed special cine cameras. From an operational point of view they are all similar. The cine film is exposed by light entering the camera through the lens and through the *aperture*, which can be rectangularly shaped, as seen in figure 1-18, or square. The camera *shutter*, also shown in the figure, is simply a disc that has a portion cut out. The shutter rotates to open the aperture when the film is in position for the exposure of a frame and to close the aperture when the film is advanced. The *pulldown* mechanism advances the film intermittently while the *pressure plate* maintains close contact between the film and aperture during exposure. (See fig. 1-19.)

One of the problems with some cine systems is that X-radiation creating the fluoroscopic image is continuous. By continuous we mean that X-radiation is produced when the aperture is closed as well as when it is open. With a single-phase generator this causes some frames of the film to receive more exposure than others, thus resulting in uneven densities on the frames. Continuous X-ray production with a three-phase generator eliminates the uneven densities. However, continuous X-ray production with both types of generators exposes the patient to about twice the radiation needed for filming because the radiation exposure when the shutter is closed does not contribute to the exposures of the frames. The solution to the radiation dosage problem is the use of a grid-controlled tube which has the capability to synchronize the X-ray exposure to the shutter-open phase of camera operation. (A grid-controlled tube is discussed in chapter 1, volume 1.) When the shutter and X-ray tube are synchronized, the patient only receives radiation exposure during the shutter-open phase.

Since the X-ray exposure is intermittent, as described above, the fluoroscopic image as viewed through the periscope during cine recording usually displays some degree of *flicker*. However, it does not interfere with monitoring of the fluoroscopic image.

Exercises (613):

Indicate whether the following statements pertaining to the operation of a cine camera are true or false. If you indicate "false," explain your answer.

T F 1. A cine camera is similar to a regular motion picture camera.

T F 2. The rotating disc, which opens and closes the aperture, is the pulldown mechanism.

T F 3. The cine film is advanced past the aperture by the pulldown mechanism.

T F 4. Close, even contact between the film

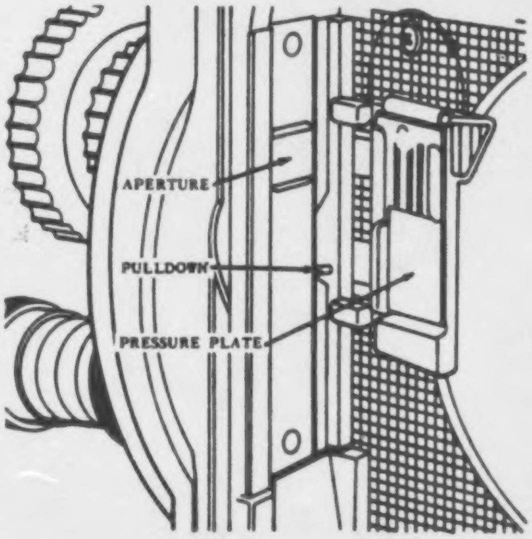

Figure 1-19. Cine camera showing the pulldown mechanism, pressure plate, and aperture.

and aperture during exposure is accomplished by the shutter.

T F 5. Continuous X-ray production results in uneven frame densities when a three-phase generator is used.

T F 6. For the most efficient use of the X-radiation during cine, the X-radiation should be produced only when the shutter is open.

T F 7. The use of a grid-controlled tube, in effect, can reduce the radiation received by a patient during cine.

T F 8. Synchronization of the X-ray tube and cine camera shutter usually produces flicker of the fluoroscopic image.

614. Compare the qualities of different cine films.

Cine film. Both 16-mm and 35-mm films are used for cinefluorography. The choice of which type to use rests with your radiologist. Some radiologists feel that 35-mm has higher resolving capabilities because there is less quantum mottle. Quantum mottle results when the number of X-ray photons per unit area is low, causing a significant uneven distribution of the photons projecting the image. Since 35-mm film requires a higher exposure, this statistical fluctuation of the X-ray photons is less significant than that with 16-mm film.

Another generally accepted way to evaluate the resolution capabilities of a cine recording system is to consider the resolving power of the weakest part of the system. During cine the "weakest link" in the resolution chain is normally the image tube itself. Cine films have the capability to resolve many more line pairs than image tubes. Therefore, this would seem to indicate that the type of cine film used does not affect resolution.

The above discussion is not meant to imply that all 35-mm cine films, for example, appear the same when processed and projected for viewing. Films differ in such characteristics as contrast, speed, and graininess. Ideally, a cine film should exhibit high contrast, be fast, and contain fine grains. In actual practice, however, the best of these three characteristics is not found in one type of film. For example, a fast film with high contrast usually contains large grains which reduce detail. This type of film, however, would also result in a lower radiation dose to the patient because of its speed.

Exercises (614):

1. What is quantum mottle?

2. How does quantum mottle affect resolution?

3. What cine film, 16-mm or 35-mm, has less quantum mottle and why?

4. According to the "weakest link" theory, what cine film should be used for the best possible resolution? Why?

5. If you use high speed cine film with high contrast properties, what must you sacrifice?

6. If you use fine-grained, fast cine film, what type of contrast (high or low) would be exhibited?

615. Indicate the advantages and disadvantages of television and videotape recording.

Television and Videotape Recording. One of the biggest problems with image tube fluoroscopy is the restriction placed on the fluoroscopist. As we mentioned before, he must maintain his head in a restricted position with respect to the periscope in order to view the image. Also, as mentioned before, the number of viewers is restricted. *Television* monitoring of the fluoroscopic image alleviates these problems. With television the fluoroscopist views the fluoroscopic image on a monitor similar to a regular commercial television set. Therefore, the position of his head is not critical. Also, several persons can view the monitor simultaneously. In fact, additional monitors can be located and viewed outside the fluoroscopic room. You can see the obvious advantage in teaching situations.

Television does have some drawbacks. One major disadvantage is the added expense for purchase and maintenance. Television equipment is quite expensive and, due to the complexity of the components, requires high cost maintenance. Another disadvantage is that the quality of the fluoroscopic image is poorer than that from direct periscope viewing. This loss of detail, however, is of little consequence for many fluoroscopic examinations.

Television also permits videotape recording of the fluoroscopic image. When videotape is used, the fluoroscopic image can be replayed on a monitor instantly; whereas, with cine the film must be processed before viewing. Significance of the "instant replay" is that the radiologist can determine immediately whether or not he has recorded the information he desires. Thus, the examination can be repeated without delay if it is not satisfactory.

The videotape image is of relatively poor quality when compared with cine. However, this problem is easily alleviated by using cine recording in addition to videotape recording.

Exercises (615):

1. What advantage does the television monitor have over periscope viewing?

2. What are the disadvantages of television fluoroscopy?

3. Give one advantage and one disadvantage of videotape recording.

1-3. Contrast Study Preparations

Now that we have discussed the anatomy and physiology of the digestive system and fluoroscopic fundamentals, we turn our attention to two general aspects of contrast studies of the digestive system. Topics include patient preparation and contrast media.

616. Indicate why patient preparation is important and specify how instructions are administered.

Patient Preparation. The specific preparatory instructions you give to your patients scheduled for a contrast study of some part of the digestive system depend upon the desires of your radiologist. The important feature of the instructions is that they should result in the part under study or related structures being free from food, liquids, gas, or fecal material. The obvious reason for the preparation is that presence of the materials mentioned may result in difficulties in interpretation due to "confusing" shadows seen during fluoroscopy or on the radiographs.

Your role in preparing the patient is usually limited to providing him with detailed, written instructions. Prepare the instruction forms and necessary supplies, such as pills, suppositories, etc., in advance so that all patients receiving the same examination receive the same instructions no matter which technician schedules him. The instructions should be clear so that the patient understands exactly what he is to do and when he is to do it. If you provide him with a laxative, include in the instructions the nature of its action. If the examination calls for ingestion of selected foods, specify the foods allowed. Do not simply state in the instructions for him to remain on a low residue diet for three days. Also, be sure to include the phone number of your department on the instruction form so that the patient can quickly contact you if questions arise.

When the patient arrives for his examination, it is usually a good idea to ask if he followed the instructions given him. For example, he may forget and eat breakfast on the morning of his upper gastrointestinal (GI) series. If you can identify this situation before the radiologist begins fluoroscopy, you can save everyone concerned from wasting their time, because the radiologist almost always cancels the examination. Also, if the pills you gave the barium enema (BE) patient "didn't

work," the radiologist may request a flat plate of the abdomen before fluoroscopy to check for gas and fecal material in the colon.

Exercises (616):

1. Why is it important for the patient to be properly prepared before an examination of certain parts of the digestive system?

2. List five key points to remember when you prepare patient instructions.

3. How and why should you follow up on the patient's preparation?

617. Indicate the types, uses, and preparation procedures pertaining to the contrast media used for the digestive system.

Contrast Media. There are several types and brands of contrast media used during contrast examination of the digestive system. Like many other aspects of radiology, your radiologist uses the contrast medium that provides him with the diagnostic information consistent with the requirements of the examination. The specific contrast medium used depends upon your radiologist; however, we provide you with some general information about the types of media.

Barium sulfate preparations. Barium sulfate preparations are available under many different brand names. Some examples are Barosperse, Barotrast, Colonatrast, Oratrast, Esophotrast, Micropaque, E-Z-Paque, and Sol-O-Pak. Depending upon how supplied, they are used for visualization of the pharynx, esophagus, stomach, small bowel, and colon. Commercial paste or cream preparations are used for examination of the pharynx and esophagus. This and other barium sulfate pastes characteristically adhere to the mucosa for a long period of time and help you to "catch" the medium in the right area. Other barium sulfate preparations are supplied usually in powder form and are mixed with water before use. Some are prepackaged in disposable barium enema kits. When mixing these preparations with water, mix the *exact* proportions desired by your radiologist.

Some barium sulfate powders are micronized and ionized so that they stay in suspension longer. When mixing preparations, such as this, do not use a mechanical mixer or metal spoon, or mix them in a metal container because the metal can provide a conducting pathway that results in neutralization of the ionized particles. This would also neutralize the suspension property of the powder and cause the powder to settle out of suspension quicker. Some settling does occur in most preparations if allowed to stand more than a few minutes. Therefore, you should stir the preparations immediately before use if they have been allowed to stand for that period of time.

Alternate digestive system media. Oral Hypaque and Gastrografin are examples of contrast media that are sometimes used for examinations of parts of the digestive system when a barium sulfate preparation is contraindicated. They are supplied in powder or liquid form. The powder is simply mixed with water before use. These types of contrast media are usually selected for use by your radiologist if a perforation is suspected.

Cholecystopaques. Contrast media normally used to examine the gallbladder and biliary tree are sometimes called cholecystopaques. Some examples of oral cholecystopaques used to examine the gallbladder are Bilopaque, Oragrafin, and Telepaque. They are supplied in tablet, capsule, or powder (to be mixed with water). An example of an injectable cholecystopaque used for intravenous cholecystography or intravenous cholangiography is Cholografin. Operative, T-tube, and transhepatic cholangiograms are usually performed, using a water soluble injectable medium, such as Hypaque or Renografin.

Other types of media. Two other types of contrast media are frequently used to examine portions of the digestive system. Air is used for a double contrast study of the colon. Air (carbon dioxide) is also introduced into the stomach by means of a carbonated beverage to provide an air contrast study of the fundus. An oily contrast medium, such as Pantopaque, or a water soluble injectable, such as Hypaque, is normally used to visualize the salivary ducts during a sialogram.

As mentioned previously, your radiologist determines the contrast medium used in your department. One example of why he makes this decision is in case of a patient with a suspected tracheo-esophageal fistula. If a contrast medium is introduced into the esophagus, it may end up in the lungs. Certain types of contrast material may be dangerous to the patient if introduced into the lungs. Consequently, in case of a tracheo-esophageal fistula, a contrast medium introduced into the esophagus must be safe with respect to the lungs. In recent years, studies have shown that contrast materials other than those normally used in the past may be better suited for this examination. Therefore, we cannot overemphasize the importance of your radiologist deciding upon the contrast medium.

Exercises (617):

1. What is the radiographic significance of commercial barium sulfate cream or paste preparations?

2. What proportions should you use when mixing barium sulfate with water?

3. What type of barium sulfate powder should not be prepared for administratively using a mechanical mixer, metal spoon, or metal container and why?

4. What action should you take immediately before using a barium sulfate preparation if it has been allowed to stand for a few minutes? Why?

5. If barium sulfate is contraindicated for use in the digestive system of a patient, what two brands of media can be considered by your radiologist?

6. Why should a patient be given a carbonated beverage during an upper GI series?

7. A patient is suspected of having a tracheo-esophageal fistula. What does this tell you about the contrast medium used to demonstrate the abnormality?

8. Who selects the contrast medium for an examination, such as in exercise number 7 above?

1-4. Radiographic Considerations

In this, the final section of this chapter, we discuss various radiographic aspects of the different contrast studies of the digestive system. We begin with sialography.

618. Answer key questions pertaining to the performance of a sialogram.

Sialography. The salivary ductal systems are demonstrated by injecting a contrast medium into the main duct of each gland that opens into the mouth. As a general rule, the procedure is a simple one—your radiologist injects the contrast medium and you perform the necessary radiographs. Some radiologists prefer to fluoroscope the gland under examination and make spot films.

Special supplies. While the supplies used for a sialogram vary from one radiologist to another, the following are frequently used:

a. A small probe to locate and explore the main duct.

b. A small bore polyethylene catheter or blunt needle through which to inject the contrast material.

c. A small syringe (2.5 or 5 cc capacity) with which to inject the contrast material.

d. A local anesthetic, injectable or viscous, to anesthetize the area about the main duct opening.

e. A lemon, cut in quarters. The lemon sometimes serves two purposes: (1) to stimulate the gland so that the duct opening can be easily located due to the discharge of saliva, and (2) to evacuate the contrast material after the initial "filled" radiographs are obtained. (Note: A postevacuation radiograph is usually made to check the degree of evacuation.) If the contrast material is not completely evacuated before the patient leaves the department, the radiologist may ask the patient to continue stimulation of the gland for 1 to 3 days through the use of lemon slices, lemon juice, or chewing gum.

Sialographic projections. The specific projections used for a sialogram, as a general rule, depend upon the particular gland under examination.

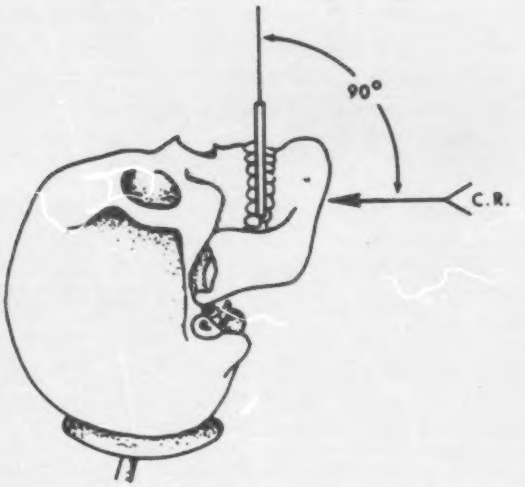

Figure 1-20. Inferosuperior or intraoral projection of the sublingual and anteromedial portions of the submaxillary glands.

a. A tangential projection, either anteroposterior (AP) or posteroanterior (PA), is usually made if the parotid gland is being examined. The gland is located approximately halfway between the anterior and posterior surfaces of the patient so part-film distance is the same for each projection. Adjust the head until the infraorbitomeatal line is perpendicular to the film. Rotate the patient's face 25° to 35° toward the side being examined or until the parotid area is perpendicular to the film. Direct the C.R. perpendicularly to the film.

b. A "straight" lateral projection can be made to visualize either of the three salivary glands. Extend the head slightly and position the skull in the true lateral position with the gland under examination nearest the film. Direct the C.R. perpendicularly through the appropriate gland to the center of the film. Various other lateral projections are sometimes made, depending upon your radiologist's desires. He may prefer a lateral with the patient's face rotated 15° downward (toward the tabletop) to visualize the parotid gland. Also, true lateral positions of the skull with the C.R. directed 10° to 30° cephalic are sometimes made to demonstrate either salivary gland.

c. The entire sublingual gland areas are usually demonstrated by using an inferosuperior or intraoral projection. Simply place an occlusal film as far into the patient's mouth as possible without causing undue discomfort, and direct a horizontal C.R. to the center of the portion of the film in the patient's mouth. (See fig. 1-20.) A portion of the submaxillary gland can also be demonstrated by this projection.

Exercises (618):

1. Why is a small probe used when performing a sialogram?

2. In place of a small bore polyethylene catheter, what can be used to introduce the contrast material?

3. Why is a lemon necessary in performing a sialogram?

4. What salivary glands are demonstrated on the straight lateral projection?

5. Should a tangential PA or a tangential AP projection be made of the parotid gland?

6. What approximate degree of rotation should be used for a tangential projection of the parotid gland?

7. What gland is probably being demonstrated if a lateral projection is made with the patient's face rotated 15 degrees downward?

8. What gland is entirely demonstrated with the intraoral projection?

9. If an AP tangential projection of the right parotid gland is being performed, in what direction is the patient's face rotated?

10. What range and direction of C.R. angulation is used for lateral projections of the salivary glands?

619. Indicate major procedures and various influential factors pertaining to contrast radiography of the pharynx and esophagus.

The Pharynx and Esophagus. Contrast studies of the pharynx and esophagus, with the exception of "heart" esophagrams, are usually made after fluoroscopy. In many cases, the radiologist makes spot films or records the parts using cine. Our discussion is directed toward ways to "catch" the contrast media during post-fluoro radiography and the projections that are usually made.

Pharynx. Examinations of the pharynx (oropharynx and laryngopharynx) using barium sulfate are somewhat difficult to make because the bolus very quickly descends through the area during deglutition (the act of swallowing). This causes many technicians to be "late" with their exposure. Also, the patient may not respond promptly to your instruction to swallow, which can cause you to make the exposure too early. One of the best ways to time the exposure to coincide with the barium-filled pharynx is to watch the patient's thyroid cartilage (Adam's apple). During deglutition the thyroid cartilage moves up and forward and then relaxes back to its normal position when the process is completed. Make your exposure immediately when the cartilage reaches its most anterosuperior position. At that instant, the oropharynx and laryngopharynx are usually filled with barium. The posterior portion of the oral cavity is also well visualized at the peak of the swallowing process.

Esophagus. Most radiographic examinations of the esophagus are made after the fluoroscopic phase of an upper GI series and to demonstrate enlargement of the heart.

Some radiologists have included in the routine of post-fluoro, upper GI films, a radiograph of the entire esophagus. Usually, the projection is made with the patient recumbent in the right anterior oblique (RAO) position because the position presents a larger space between the heart and spine and, consequently, permits a more unobstructed view of the lower esophagus. The entire esophagus can usually be demonstrated filled with barium if the patient is allowed to drink the liquid barium through a straw continuously (drinking esophagram), beginning four or five seconds before the exposure. Of course, the exposure can be made after the patient swallows a single mouthful of liquid or paste barium, but the chance of demonstrating the entire esophagus filled with barium is lost. A commercially prepared barium paste usually shows the outline of the entire esophagus, due to the special coating characteristics of the medium, but the entire esophagus is usually not filled.

Radiographic projections of the esophagus to demonstrate enlargement of the heart should be made with the patient erect, at a 72-inch distance, and after full inspiration. One reason for these conditions is that the visible size of the heart is evaluated on the radiographs in addition to possible displacement of the esophagus as a result of heart enlargement. Also, the pulmonary structures are evaluated because pulmonary changes may occur with heart enlargement.

Four projections of the chest with the esophagus outlined with the contrast medium are usually made—posteroanterior (PA), left anterior oblique (LAO), RAO, and left lateral. The left lateral is made as opposed to the right to minimize the part (heart) film distance and the resulting magnification. The degree of rotation for the obliques varies slightly among radiologists; however, the RAO is usually 45° while the LAO is normally 55 to 65. The reason the obliquity is different for each oblique is that, since the heart is located somewhat to the left of the midline, the LAO requires more rotation to project the heart clear of the spine.

You can obtain better results if you use barium paste for the heart series—specifically a commercial paste with special coating properties. Most radiologists can evaluate the esophagus as long as it is outlined by the paste rather than being filled by the liquid barium. The exact timing of the exposure is largely a matter of personal preference on the part of the technician. It also depends on the thickness of the paste and cooperation of the patient. Some technicians ask the patient to swallow a mouthful of paste and immediately take a breath—the exposure is then made immediately after the breath or after a delay of 1 to 4 seconds. The time lapse depends upon the thickness of the paste. Other technicians have the patient swallow one mouthful of paste, give him another to hold, and then repeat the above procedure. The first mouthful increases the possibility for good esophageal coating.

There are two other factors you should keep in mind while performing this examination. First, the PA exposure should be increased slightly over the normal PA chest exposure to permit visualization of the lower esophagus through the superimposed heart. Second, displacement of the esophagus by the great vessels is usually evaluated so it is important to outline the middle third of the esophagus as well as the distal third. Some radiologists do not care about the demonstration of the proximal third when a heart series is performed.

Exercises (619):

1. Why is it difficult to produce barium-filled radiographs of the pharynx?
2. Explain one way to synchronize your exposure with the act of swallowing to radiograph the contrast-filled pharynx.
3. Why is the esophagram performed in conjunction with an upper GI series usually performed with the patient in the RAO position?
4. Describe the drinking esophagram.
5. How does the drinking esophagram radiograph differ from the "single-swallow" or "paste" radiographs in the visualization of the esophagus?
6. Why should esophagrams for heart evaluation be made with the patient erect, at a 72-inch FFD, and on full inspiration?
7. Why is a left lateral esophagram performed instead of a right lateral for a heart series?
8. Why is the LAO heart series radiograph rotated more than the RAO?
9. What type of barium sulfate preparation produces the best results for a heart series?
10. What three factors influence timing of the exposure during a heart series?
11. Why should the PA heart series radiograph be made with a slight increase in exposure over a normal PA chest?
12. Why is it important to visualize the middle third of the esophagus during a heart series?

620. Cite fundamentals of hypotonic duodenography and describe the projections used for an upper GI series.

The Stomach and Duodenum. Examination of the stomach and duodenum, as you know, is made by a combination of fluoroscopy with cine or spot filming, and "followup" or "overhead" films.

Delay in gastric evacuation. At times during the fluoroscopic phase of the examination, the contrast medium is slow to empty into the duodenum, preventing visualization of the all-important duodenal bulb and the remainder of the duodenum. If the radiologist elects to have the patient wait outside the exposure room so that the next patient may be examined, he, the radiologist, may ask you to have the patient lie down to speed up the evacuation of the stomach. When the situation arises, have the patient lie in either the right anterior oblique or right lateral position. It is in these positions that peristalsis is maximal due to the influence of gravity.

Hypotonic duodenography. Hypotonic duodenography is examination of the duodenum without interference from peristalsis. It enables the radiologist to more effectively evaluate the mucosa of the duodenum. The examination may be accomplished in conjunction with a standard upper GI series. The patient is given an injection of pro-banthine or a similar drug which temporarily decreases the tone of the walls and dilates the duodenum.

The examination may also be scheduled separately in which case the barium may be introduced by means of a tube or by oral ingestion. The drug is always administered after the contrast medium. The radiologist may or may not require followup films. However, he almost always records the duodenum by using spot films or cine.

A side effect stemming from the injection of pro-banthine is loss of control of the voluntary muscles, including control of the respiratory muscles. If this condition occurs, artificial respiration must be administered until the effects of the drug have subsided. Consequently, your emergency tray containing resuscitation equipment should be readily available.

Projections. The specific followup projections you accomplish during an upper GI series vary from one radiologist to another. Five such projections are commonly performed. We discuss them from the aspect of the anatomy demonstrated. The duodenum is demonstrated fairly well in most of the projections with the exception of the bulb, as will be noted.

a. The PA projection shows the general contour of the stomach and duodenal bulb. If taken erect, it also reveals the true size, shape, and relative position of the stomach.

b. The left posterior oblique (LPO) shows an air contrast view of the body, pylorus, and duodenal bulb. The fundus is shown filled with barium.

c. The RAO, on all patients except for the hypersthenic individual, provides the best demonstration of the pylorus and duodenal bulb. The degree of obliquity required to present the pylorus and bulb in profile (which shows them best) depends upon the size, shape, and position of the stomach. Some radiologists request a standard 45° oblique while others want two or more obliques with varying degrees of rotation. Your radiologist may also request two radiographs made with the patient in the same oblique position to take advantage of the maximal peristalsis in that position.

d. The right lateral projection provides a profile view of the pylorus and duodenal bulb in a hypersthenic individual because those parts are usually aligned in an anteroposterior direction. This patient is sometimes referred to as having a "posterior bulb."

e. The erect left lateral is the best projection to show the relationship between the stomach and retrogastric structures.

Exercises (620):

In the following exercise pertaining to an upper GI series, fill in the blank spaces with one or two words, as appropriate.

1. The ________________ oblique and ________________ positions should be used to promote gastric evacuation because ____________ is maximum.
2. A hypotonic duodenal examination permits better evaluation of the duodenal ____________.
3. The drug used in hypotonic duodenography decreases the tone of the __________ of the duodenum.
4. In hypotonic duodenography the introduction of the ___________ always precedes the introduction of the _______.
5. The drug used in hypotonic duodenography may cause loss of control of the ___________, necessitating ____________ until the drug effect subsides.
6. The _______ projection of the stomach and duodenum reveals an air contrast view of the stomach (except for the fundus) and duodenal bulb.
7. The RAO presents the best view of the ___________ and ________________ on most individuals.
8. Two identical right anterior oblique projections may be made to take advantage of ____________.
9. For a patient with a posterior bulb, a profile view of the bulb is obtained with a __________ projection.
10. The erect left lateral projection is best to demonstrate the relationship between the stomach and ______________.

621. Differentiate among the four methods of contrast examinations of the small bowel.

The Small Bowel. There are four methods by which contrast examination of the small bowel is performed. They are: (1) frequent interval method, (2) cold isotonic saline method, (3) intubation method, and (4) retrograde method.

Frequent interval method. The frequent interval method is often done in conjunction with an upper GI series. The barium is simply followed on 14 x 17 PA or AP radiographs taken at specific intervals—usually 30 minutes. Some radiologists inspect each film immediately so that they can examine the patient under fluoroscopy if a suspicious area is present. The last 14 x 17 radiograph taken is the first one that shows the head of the column of barium in the large bowel. At that time the radiologist usually examines the patient fluoroscopically to evaluate and perhaps make spot films of the ileocecal valve.

In addition to demonstrating structural variations of the small bowel, the frequent interval method is also used to evaluate the *motility* of the small bowel. The radiologist determines the time it takes for the stomach to empty and the time required for the barium to reach the colon. Consequently, you should include time markers on the radiographs. In addition, include the stomach on the radiographs at least until it is empty.

Cold isotonic saline method. The cold isotonic saline method involves mixing the barium powder with cold isotonic saline instead of plain water. The saline hastens stomach evacuation and motility through the small intestine. The barium may be mixed with saline as described above, or it may be mixed in the conventional manner, in which case the saline is given later. If this examination is performed in conjunction with an upper GI series, the latter procedure should be followed with the saline given to the patient after completion of the standard upper GI followup films. In place of saline, plain cold water may also be used to shorten stomach evacuation and small bowel transit time. The water may be given at various intervals throughout the examination, or it may be given only after completion of the followup films.

If a considerable amount of saline or water is given, the contrast medium tends to become diluted; consequently, some contrast and detail are lost. However, this method does reduce the transit time considerably, allowing the barium to reach the colon quicker—thus reducing the overall time for the examination. Also, the radiologist can more readily follow the head of the column of barium fluoroscopically. The reason for this is that the barium moves fast enough to make it practical for him to monitor most or all of the barium movement to the colon. Naturally, with this method, normal stomach evacuation and transit time cannot be evaluated.

Intubation method. If the contrast medium cannot be administered orally as in the two previously described methods, it may be given through a tube introduced into the small bowel from above. The intubation has a definite advantage over all other types of small bowel examinations in that the contrast medium can be introduced directly into a small bowel segment. This allows visualization of the segment under study without interference from other portions of the small bowel because of superimposition.

Retrograde method. Most rarely performed is the retrograde method, also called reflux method, of small bowel examination. The contrast medium is introduced by a barium enema. The reflux of the contrast medium through the ileocecal valve enables the small bowel to be demonstrated. This method is usually used to detect organic filling defects.

Exercises (621):

Match the method of small bowel examination in column B with the appropriate statement or phrase in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once.

Column A

_ 1. Evaluates small bowel motility.
_ 2. Depends upon reflux.
_ 3. Medium is introduced directly into a small bowel segment.
_ 4. Medium passes rapidly through the small bowel.
_ 5. Requires time markers.
_ 6. Used to detect organic filling defects.
_ 7. Permits study of a small bowel segment without interference from superimposition.
_ 8. Uses barium enema.
_ 9. Makes use of cold water.
_10. Hastens stomach evacuation.
_11. Include stomach on radiographs until it is empty.

Column B

a. Frequent interval method.
b. Cold isotonic saline method.
c. Intubation method.
d. Retrograde method.

622. Specify fundamental procedures involved in air-contrast studies of the colon.

The Large Bowel. Examination of the large bowel varies from one radiologist to another. Basically, two types of examinations are performed—the barium enema and the double-contrast or air-contrast study. As a general rule, the air-contrast study is performed by one of two methods—direct or two-stage.

Direct and two-stage air-contrast studies. The direct air-contrast study is performed simultaneously with the barium enema. A relatively small amount of barium sulfate is

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introduced into the colon, followed by air. The major difference between the direct and two-stage methods is that with the direct method the barium is not evacuated before the air is introduced. Naturally, the direct method requires equipment that allows you to switch immediately from barium to air during fluoroscopy. If your department uses an irrigating can or similar set-up, including certain disposable enema kits, as the barium container, you will have to rig a Y-connector to the tubing so that air or barium can be introduced into the colon. Some disposable kits are especially designed for direct air-contrast studies eliminating the requirement for a special connector.

Another special type of device that allows direct air-contrast studies is the pneumocolon. The pneumocolon consists of a wide-mouthed bottle which has a specially designed lid assembly incorporating two tubular channels and a triangular-shaped support. One of the channels serves as an inlet and the other as an outlet, with respect to the inside of the bottle. Air pressure is built up within the bottle by pumping air into it by means of the attached hand pump. When sufficient air pressure is built up within the bottle and the clamp on the outlet tube is opened, the barium preparation flows into the colon as a result of the air pressure in the bottle. For barium flow to take place, however, the orifice of the outlet channel must be submerged in the liquid. This is done by placing the bottle so that the long side of the triangular support is down, as shown in figure 1-21. To introduce air into the colon, simply turn the bottle so that either of the two short sides of the triangular support is down. These positions remove the orifice of the outlet channel from the liquid and place it in the air space above the level of the liquid. (See fig. 1-22.)

The two-stage method of air-contrast examinations is performed as follows: After a standard barium enema, the patient evacuates the contrast medium and is returned to the table. Air is then introduced into the colon, usually by means of a single tube to which is attached an enema tip and air bulb.

Exercises (622):

1. What is the major difference between the

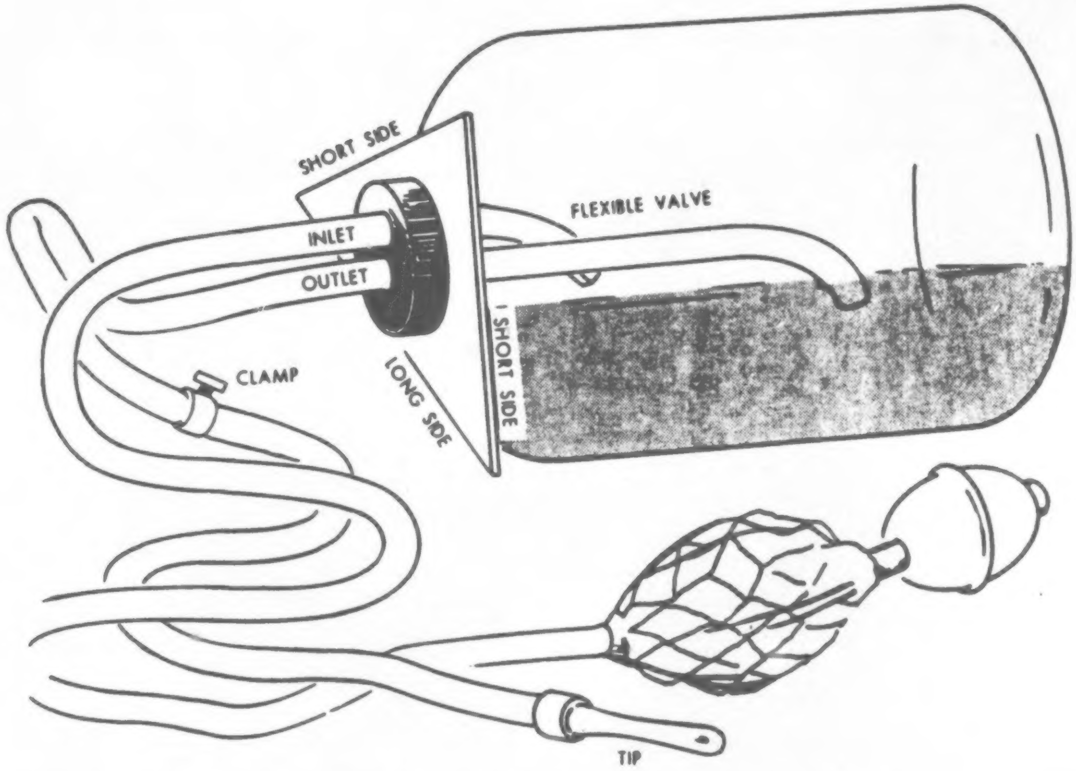

Figure 1-21. Position of the "Pneumocolon" for the introduction of the barium.

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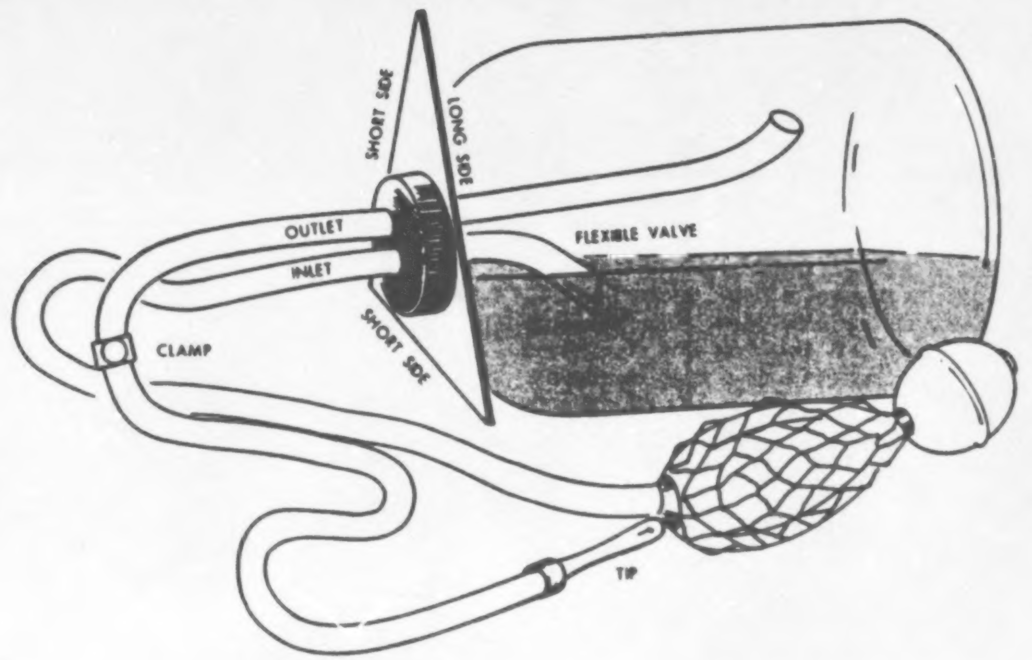

Figure 1-22. Position of the "Pneumocolon" for the introduction of air.

direct and two-stage methods of air-contrast studies of the colon?

2. The equipment for introducing the contrast media during a direct air-contrast study must differ from that of a two-stage study in what way?

3. Does the pneumocolon provide the flexibility indicated in exercise number 2 above?

4. Does the pneumocolon use air pressure or gravity to introduce the liquid?

5. What is the position of the triangular support of the pneumocolon to introduce barium? To introduce air?

623. Given a list of statements pertaining to preparation of the barium liquid for colon examinations, indicate which are true and which are false.

Preparation of the barium solution. You should always prepare the barium sulfate for a colon examination according to your radiologist's desires. Most radiologists like the temperature of the liquid to be about 85° F, while others like it slightly warmer. A few of them want the temperature to be considerably colder, about 41° F. Naturally, if this low temperature is desired, you will either have to mix the preparation in advance and refrigerate it, or mix the barium sulfate with refrigerated water. In either case, to insure the correct temperature, use a thermometer rather than estimate the temperature. Also keep in mind that the temperature of a solution that is allowed to stand at room temperatures for a long period of time will either increase if it is around 41° F or decrease if around 85° F. In view of the changing temperature, it is usually best to mix the solution immediately before each examination. However, if this procedure is not possible, maintain the correct temperature by allowing the solution container to remain in water of the corresponding temperature.

The thickness of the barium sulfate solution for a colon examination also varies. The ratio of barium sulfate to water ranges from 1 part barium to 4 to 8 parts water by volume. As far as you are concerned, the important factor is for you to *consistently* mix the thickness your radiologist wants. This means that you should have a reliable means of measuring both parts of the mixture so that the thickness can be repeated day after day. Also, you should use a hydrometer to spot check the specific gravity and therefore the thickness of the preparation. Some hydrometers cannot be used for this purpose since they are not scaled in the appropriate range. Special hydrometers are available, however, that are made especially to test the specific gravity of barium sulfate preparations. Of course, the specific gravity you use depends upon local policy.

Several other points you should keep in mind when preparing the solution are as follows:

a. Except when using a prepackaged barium enema kit, pour the barium sulfate into the water rather than the other way around. This prevents some of the powder from sticking to the container and thereby reducing the thickness of the preparation.

b. Except when using a prepackaged kit, mix the two parts of the mixture in another container to reduce the possibility of the tube becoming clogged by settled barium. Pour the mixture into the container from which it is administered immediately before use.

c. "Bleed" the tubing immediately before you insert the rectal tip, to remove the air. This step serves two purposes: (1) it tells you whether or not the solution runs freely through the tube, and (2) it prevents the air in the tube from being introduced into the colon ahead of the barium. Air introduced in this manner can interfere with good visualization of the colon.

Exercises (623):

Indicate whether the following statements pertaining to preparation of the barium liquid for colon examinations are true or false. If you indicate "false," explain your answer.

T F 1. The temperature of the liquid should always be 85° F.

T F 2. You should use a thermometer to check the temperature of the liquid rather than estimate it.

T F 3. To help insure the correct liquid temperature, you should always mix it immediately before use.

T F 4. The barium sulfate preparation is usually mixed at a ratio of one part barium to 4 to 8 parts water by volume.

T F 5. You should use a hydrometer to spot-check the thickness of your barium preparation.

T F 6. You should pour the water into the barium powder rather than pour the powder into the water.

T F 7. You should mix the preparation in a separate container except when using a prepackaged kit.

T F 8. "Bleeding the tube" prevents air-lock.

624. Provide specific facts about the projections taken of contrast colon examinations.

Projections. The follow-up projections taken in conjunction with a colon examination may consist of a standard "routine" or the radiologist may vary them according to his fluoroscopic findings. In either case, there are several that are performed. As a general rule, the 14- x 17-inch film should be centered to the iliac crest for all projections except those indicated below. Also, when a large patient is examined, it is very difficult and sometimes impossible to include the entire colon on a single film. When such is the case, use two films crosswise instead of one lengthwise for the AP or PA. Oftentimes, you can include the entire colon on the obliques when it is not possible to do so on the PA or AP.

When performing air-contrast radiographs, you should rotate the patient 360° before performing each radiograph to recoat the walls of the colon with the barium. For example: if the patient is supine and you wish to perform a right lateral decubitus, rotate him 360° to the supine position before turning him on his right side for the decubitus projection.

PA, AP, and 45 degree anterior or posterior oblique projections are frequently made of the colon. On the PA and AP radiographs, the hepatic and splenic flexures and the sigmoid colon are usually not seen well because the loops are overlapped. The LPO or RAO usually provides an unobstructed view of the splenic flexure and sigmoid colon while the RPO or LAO does the same for the hepatic flexure.

A lateral projection of the rectum is also frequently performed. For this projection, align the patient so that a coronal plane 2 inches posterior to the midaxillary line is centered to the midline of the table. Direct the C.R. perpendicularly through a point on the coronal plane 2 inches superior to the symphysis pubis.

The sigmoid colon and rectum are also demonstrated by placing the patient in the LPO position and directing the C.R. 2 inches medial to the right (elevated) anterior-superior iliac spine at an angle of 30 degrees to 35 degrees toward the head. Also, the supine position is used with the same C.R. angulation and direction or the prone position with a caudally angled C.R. (also 30° to 35°).

The *Chassard-Lapine* projection also demonstrates the sigmoid colon and rectum. (See fig. 1-23.) Seat the patient on the side of the table and have him abduct his femurs so they will not interfere with the flexion of his body. Have him lean forward as far as possible and hold his ankles for support. Direct the C.R. perpendicularly through the midline of the lumbosacral region at the level of the greater trochanters to the center of the film. The exposure for this projection should be approximately the same as that required for a lateral projection of the rectum.

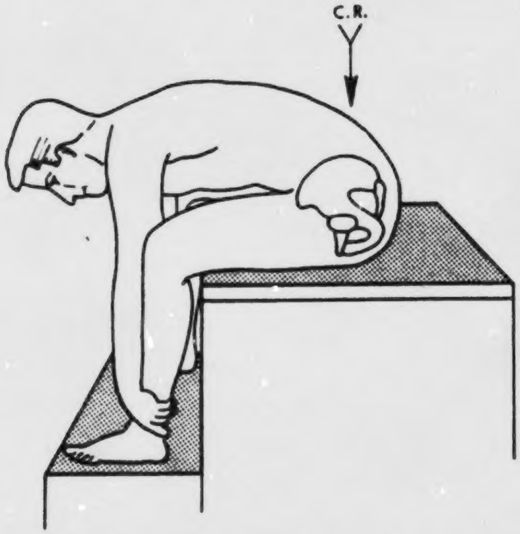

Figure 1-23. Chassard-Lapine projection.

As a rule, some projections of the air-contrast study are performed with a horizontal C.R. to demonstrate the air/fluid levels. Both lateral decubitus projections are almost always included. Also, erect AP or PA projections are usually performed. Keep in mind that even though the thickness of an abdomen is the same, you should reduce your exposure slightly from normal when performing air-contrast projections because of the radiolucency of the air.

Exercises (624):

1. Where should 14- x 17-inch cassettes be centered for most colon radiographs?

2. What action should you take with regard to the AP or PA projection of the colon on a large patient that is being examined?

3. Why should the patient be rotated 360° before performing each radiograph of the colon during an air-contrast examination?

4. What parts of the colon are not visualized on the AP or PA projection?

5. What oblique projection(s) provides an unobstructed view of the splenic flexure and sigmoid colon? The hepatic flexure?

6. How should the patient and C.R. be aligned for a lateral rectum?

7. List three positions in which the C.R. is

angled that demonstrate the sigmoid colon and rectum. Give the angle and direction of the C.R. for each.

8. What part(s) of the colon is demonstrated on the Chassard-Lapine projection?

9. What relative exposure should be used for the Chassard-Lapine projection?

10. Why are some air-contrast radiographs of the colon taken with a horizontal C.R.?

11. What relative exposure should be used for air-contrast projections of the colon? Why?

625. Answer key questions pertaining to the performance of an oral cholecystogram.

Gallbladder and Biliary System. Examination of the gallbladder is usually accomplished by an oral cholecystogram although occasionally it can be demonstrated by the intravenous injection of contrast medium. The biliary ductal system is examined either by intravenous, T-tube, transhepatic, or operative cholangiography.

Oral cholecystography. The gallbladder is located anywhere from the level of the right eighth rib to well below the iliac crest on the right side. Also, with regard to its medial/lateral location, it is superimposed over the spine; located near the lateral wall of the abdomen or anywhere in between. The precise location depends for the most part on the patient's body habitus. In a hypersthenic individual, it is usually located high in the abdomen toward the lateral wall; while in the asthenic or hyposthenic individual, it is usually located lower, and nearer the spine. In addition, the gallbladder "moves" from one location to another as you change the patient's position to perform the various radiographs.

With the exception of the scout film, radiographs of the gallbladder should be made with a small cone field, no larger than 6 inches by 6 inches. Consequently, you can see that it is important for you to properly locate the gallbladder with the scout film so that you can perform the remainder of the radiographs with the gallbladder properly centered in the small cone field.

Most radiologists require an initial PA 10- x 12-inch scout film of the gallbladder area. The PA projection is better than the AP because the gallbladder is located more toward the anterior surface of the abdomen. Center a sagittal plane midway between the midline and the abdominal wall to the center of the table. Adjust the center of the film to the level of the 10th posterior rib. Some technicians like to leave the patient and tube in position while the scout film is being processed. After inspection of the scout, they make a mark on the patient's back directly over the gallbladder, using the lighted cone field as a reference. Other technicians prefer to tape a line of lead numbers or letters over the patient's spine and determine the location of the gallbladder with respect to the lead markers. It doesn't matter how you locate the gallbladder as long as you can accurately project it in a small cone field when performing the remaining radiographs.

If the gallbladder is not seen on the 10 x 12 scout film, the most probable cause is that it did not visualize. However, rarely it is located outside the area covered by the film. It *can* be located on the patient's left side, and while this possibility is remote, some radiologists require a 14- x 17-inch film of the entire abdomen before terminating the examination to evaluate that possibility. Also, the radiologist sometimes likes to see, in case of a nonvisualized gallbladder, whether or not contrast medium is in the stomach, small bowel, or large bowel. Occasionally, the patient does not take his pills at the prescribed time. If he took them just before coming to the radiology department, the concentration of medium can readily be seen in the stomach. The presence or absence of the contrast medium in the bowel can provide the radiologist with additional information about the nature of contrast medium absorption into the blood stream.

Depending upon the desires of your radiologist, various projections are performed of the gallbladder after the scout film. At least one projection, erect or right lateral decubitus, is made with a horizontal C.R. for two reasons: (1) small stones heavier than bile may gravitate to the dependent portion of the gallbladder and therefore be visualized more readily due to concentration, and (2) small stones lighter than bile have a tendency to stratify, also increasing the possibility of their visualization. The stratification is due to the fact that bile layers out according to the specific gravity. Small radiolucent stones float at the surface of a specific bile layer, depending upon the relative specific gravity. Keep in mind that with both the erect and decubitus projections the gallbladder will "drop" slightly, requiring you to adjust your centering point. On the erect, it usually moves inferiorly 2 to 4 inches, while on the decubitus it moves laterally 1 to 2 inches.

Other projections of the gallbladder are supine LAO, and RPO. (NOTE: The erect projection mentioned before may be taken with the patient in the LAO or RPO position. In fact, because the gallbladder normally shifts closer to the spine in the erect position, some radiologists prefer that an oblique erect projection be made to avoid superimposition over the spine.) The oblique projections are usually made routinely with 45 degrees of obliquity.

One of the problems you must overcome when performing a gallbladder series is the superimposition of gas over the gallbladder. Radiologists usually require at least one projection with the gallbladder free of overlying gas. If the routine projections reveal overlying gas, PA or oblique projections made with the patient in the Trendelenburg position may be the answer. Also, recumbent or erect obliques made with the patient rotated more or less than 45° may project the gallbladder free of gas.

To check the function of the gallbladder, a fatty meal is given to the patient and one final radiograph is made afterwards. If the original radiographs reveal stones in the gallbladder, some radiologists do not want a fatty meal given to the patient. Since ingestion of fatty foods precipitates the flow of bile to the duodenum, one or more of the gallbladder stones may also leave the gallbladder and become lodged in the cystic or common bile duct. This condition is dangerous to the patient and sometimes requires immediate corrective surgery.

Exercises (625):

1. The gallbladder is usually located within what mediolateral and superoinferior boundaries?

2. Where is the gallbladder located in a hypersthenic individual? In a hyposthenic individual?

3. What maximum size cone field should be used for all gallbladder radiographs except the scout film?

4. Where should you center the 12 x 12 film for a gallbladder scout film?

5. Although there are several ways to locate and mark the gallbladder, what is your most important concern?

6. What is the most probable cause of a "missing" gallbladder on a 10 x 12 scout film?

7. Why might you perform a 14 x 17 radiograph of a patient with a suspected nonvisualized gallbladder?

8. Why should at least one projection of the gallbladder be made with a horizontal C.R.?

9. How many inches does the gallbladder "drop" for a decubitus projection? For an erect projection?

10. Why should the erect gallbladder radiograph be made with the patient in the oblique position?

11. Give two ways to rid the gallbladder of overlying gas shadows.

12. Why should you withhold the fatty meal from a patient whose films demonstrate gallstones?

626. Differentiate between the various methods of cholangiography.

Intravenous cholecystography and cholangiography. The gallbladder and biliary ductal system can be examined by intravenous introduction of a contrast medium, such as Cholografin, especially designed to be secreted by the liver. The contrast medium usually appears in the bile within 10 to 15 minutes after injection and maximum filling of the gallbladder is reached in 2 to 2½ hours. The intravenous examination may be performed to visualize the gallbladder or ductal system or both. If the gallbladder is to be examined, it is done so by using the oral cholecystographic projections previously described after maximum filling has been reached. If the gallbladder fails to visualize in a reasonable period of time, sometimes it can be demonstrated on a film taken 24 hours later.

If the examination is primarily a cholangiogram, a series of radiographs are made usually with the patient in the RPO position rotated 15°. This oblique position is used because it clears the distal end of the common bile duct from superimposition over the spine, which occurs if the patient is in the "straight" AP position.

After a scout film to determine whether or not gas and fecal material may preclude visualization of the bile ducts, a radiograph is usually made 10 to 15 minutes after injection and thereafter every 10 or 15 minutes or so. Actually, the radiologist usually inspects each radiograph and tells you when to make the next radiograph. When he determines that the ducts are adequately visualized, he may ask for tomograms, which usually demonstrate the ducts better than the plain radiographs. Since the major ducts are located approximately midway between the anterior and posterior surfaces of the abdomen, the cuts should be in that vicinity. The specific cuts, of course, depend upon your radiologist, but usually they cover an area from 1 to 2 cm above to 1 to 2 cm below the level of the biliary ducts.

Transhepatic, operative, and T-tube cholangiography. These three types of cholangiograms are made by introducing the contrast medium directly into the biliary ducts. All of them demonstrate the ducts more clearly than the intravenous method because the contrast medium is not significantly diluted. Specific procedures for these three vary from place to place.

The contrast medium for the transhepatic examination is introduced into the ducts by means of a needle about 11 or 12 cm in length. The needle is passed from the anterior surface of the abdomen through the liver into the appropriate biliary duct. While this examination is sometimes performed in the radiology department, it is frequently performed in the operating room just prior to surgery.

An operative cholangiogram is performed during a cholecystectomy. It may be done before or after the gallbladder is removed (usually after). The contrast medium is injected directly into the biliary ducts.

A T-tube cholangiogram is performed by introducing the contrast medium directly into the biliary ducts by means of a T-tube left in place after a cholecystectomy.

Exercises (626):

Match the type of cholangiogram in column B with the appropriate statement or phrase in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition more than one column B item may match a single column A item.

Column A

_ 1. Medium is injected directly into ducts.
_ 2. Performed during surgery.
_ 3. Performed after cholecystectomy.
_ 4. Performed in the operating room.
_ 5. May also demonstrate the gallbladder.
_ 6. Usually requires RPO radiographs.

Column B

a. Intravenous.
b. T-tube.
c. Operative.
d. Transhepatic.

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Contrast Studies of the Urogenital System

THE UROGENITAL system consists of the urinary as well as the reproductive organs. Malfunction of any component of this complex system may result in permanent damage or, in the case of the urinary organs, even death. Consequently, early and accurate diagnosis of such maladies is essential for surgical or medical correction. As a rule, such diagnosis involves radiological examination of the affected component. Since you are required to assist with these examinations, you must be familiar with the structure and function of the organs involved, and also versed in the procedural steps employed to radiologically demonstrate them. We begin this chapter with a look at the anatomy and physiology of the urinary system. After that we discuss the all-important contrast media reactions and some emergency equipment, followed by the IVP, cystogram, and cystourethrogram. Finally, we discuss the anatomy and radiographic considerations of the female reproductive system.

2-1. Anatomy and Physiology of the Urinary System

The urinary system is vital to life in that it provides a means for collecting waste products from the bloodstream, filtrating and storing these products, and excreting the waste. Major portions of the urinary system are the kidneys, ureters, bladder, and urethra.

527. Given a list of statements pertaining to the anatomy and physiology of the kidneys, indicate which are true and which are false.

The Kidneys. The bean-shaped kidneys are the principal organs of the urinary system. They are situated in the retroperitoneal space, high in the posterior aspect of the abdominal cavity, and on either side of the vertebral column. Each is about 11 cm long, 5 to 7 cm wide, and 2.5 to 3 cm thick.

Surrounding structures. The superior margins of the kidneys are approximately level with the 12th thoracic vertebra. Their inferior margins are usually aligned with the third lumbar vertebra. The top of the left kidney is situated slightly higher than is the organ on the right. (NOTE: This is the usual location of the kidneys when the patient is supine. When he is erect, these organs descend a bit.) Figure 2-1 illustrates the relationship between the urinary system, the spine, the pelvis, and the rib cage.

Since the kidneys are retroperitoneal structures, they are posterior to most other abdominal organs. The liver, for example, covers the greater portion of the anterior surface of the right kidney, and the descending portion of the duodenum covers a small segment of the medial aspect of this surface. The hepatic flexure and a portion of the transverse colon cover the remaining inferior portion. The spleen covers most of the anterior surface of the left kidney, while the posterior gastric wall covers a portion of the superior aspect of this surface. The posterior pancreatic surface overlies the medial midsection. The jejunum covers the inferomedial surface of this kidney, and the inferolateral tip is covered by the transverse colon.

Not all of the abdominal structures lie anterior to the kidneys. For instance, the adrenal glands are situated on the medial and superior aspects of the upper portions of both organs. These glands are part of the endocrine system and serve no urinary function.

The diaphragm covers the superior renal surfaces and a portion of the posterior surfaces. The 12th rib usually overlies both kidneys. Occasionally, the 11th rib also overlies the upper aspect of each kidney. The remainder of both organs is covered by musculature and fatty tissue. The medical

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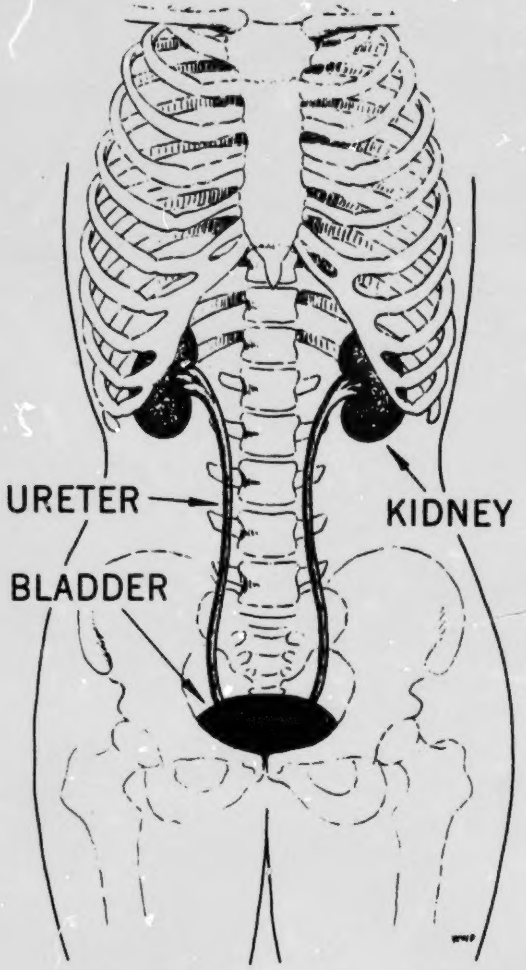

Figure 2-1. The kidneys, ureters, and bladder.

portions are close to the psoas major muscles, the central sections are just anterior to the quadratus lumborum muscle, and the inferolateral aspects are covered by the sacrospinalis muscles. Laterally, the renal organs are cushioned by layers of fatty tissue, which lie between them and the lateral walls of the abdomen.

Kidney structure. The medial surfaces of the kidneys are concave. This portion of each kidney houses the renal hila, through which the renal arteries enter the kidneys and where the renal veins and renal pelves exit. All other surfaces of the renal organs are completely covered by a layer of fatty tissue referred to as the "perirenal-fat pad." This fatty tissue serves as a shock absorber and a temperature control device for the kidneys. It also serves to separate the adrenal glands from the renal organs, a fact which becomes significant when a differential diagnosis of adrenal or renal cortical tumor masses is sought. Figures 2-2 and 2-3 illustrate the structures of the kidney. Refer to these figures as we discuss the renal components.

The *cortex* or outer layer contains the *glomeruli* and *convoluted tubules* which form the *nephron* or functional unit of the kidney. There are about one million nephron units in each kidney. The *medullary* layer of renal tissue is inside the cortex and contains the *collecting tubules*, which begin the passage for urine. The collecting tubules converge to form a series of conical masses, the renal *pyramids*, which number from 8 to 18.

The renal *sinus* is an expanded extension of the hilum. It forms the central cavity of the kidney and houses the minor calyces, major calyces, and the renal pelvis.

The *minor calyces* are a group of small, cup-shaped tubes numbering from 4 to 13. They are situated along the outer curvature of the sinus and are in close contact with the apices of the pyramids. (NOTE: The minor calyces actually surround one or more of the papillae extending through the surface of the apices.) The minor calyces, after receiving the urine from the apices of the pyramids, extend into the central portion of the renal sinus for a short distance, and then join to form the *major calyces*. These major structures are 2 or 3 short, wide tubes, which extend further into the renal sinus and then join to form the funnel-shaped *renal pelvis*. This structure leaves the kidney through the hilum, curves downward, and joins with the ureter. The minor calyces, major calyces, and renal pelvis are continuous with each other.

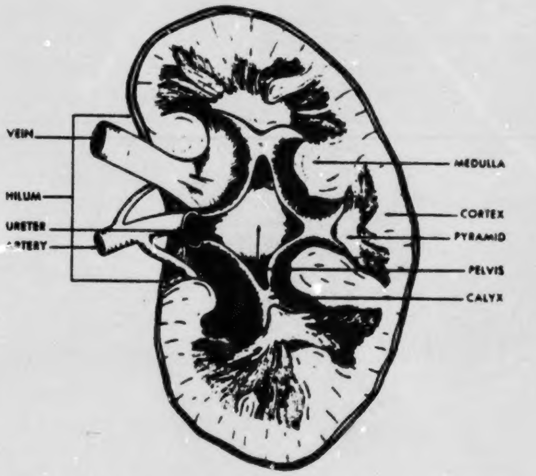

Figure 2-2. The structures of the kidney.

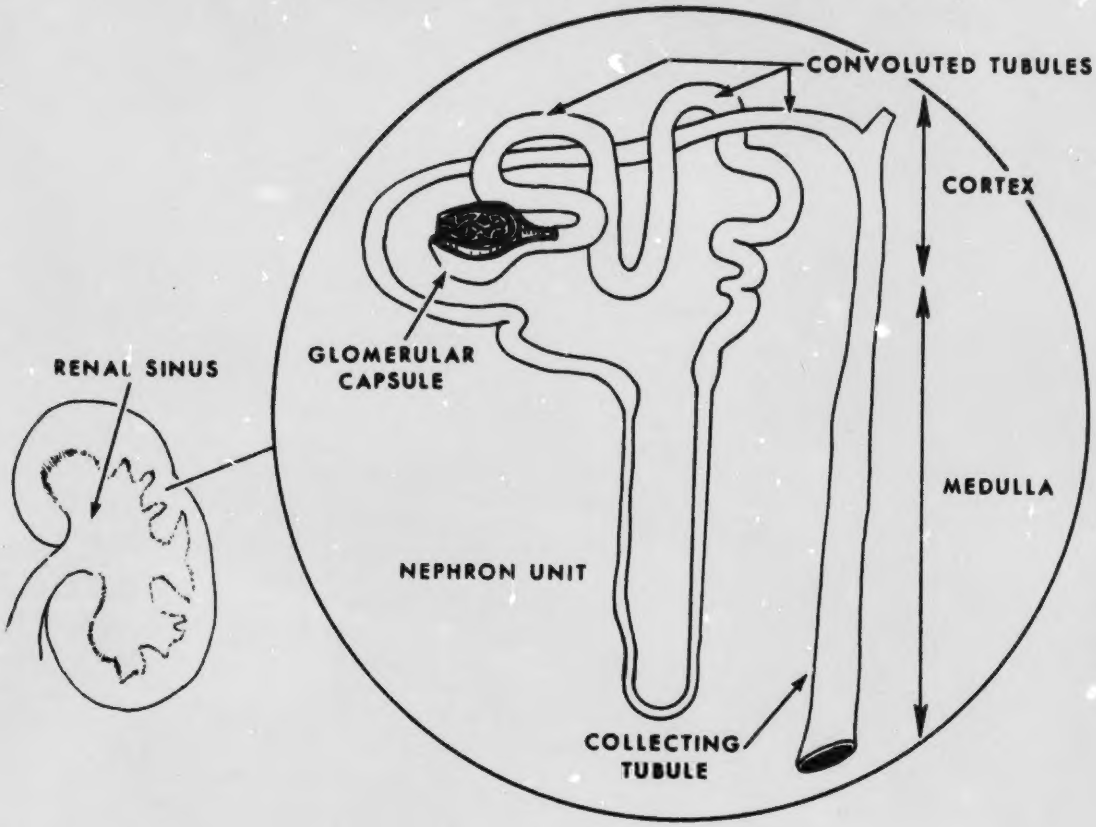

Figure 2-3. Renal sinus and nephron unit.

Exercises (627):

T F 1. The kidneys are located in the retroperitoneal space.

T F 2. The kidneys are approximately 11 cm long, 5 to 7 cm wide, and 2.5 to 4 cm thick.

T F 3. The left kidney is located more superiorly than the right.

T F 4. The tops of the kidneys are approximately level with the 12th thoracic vertebra.

T F 5. Portions of the stomach, the small bowel and the large bowel overlie the kidneys.

T F 6. The adrenal glands are located on the inferior surface of each kidney.

T F 7. The 11th and 12th ribs always overlie the kidneys.

T F 8. The medial portion of the kidney through which various structures enter and exit the kidneys is the renal pelvis.

T F 9. The perirenal-fat pad separates the adrenal glands from the kidneys.

T F 10. The outer layer of the kidney containing the nephron unit is the cortex.

T F 11. The collecting tubules converge to form the renal pyramids.

T F 12. The minor calyces receive urine from the apices of the pyramids.

T F 13. Immediately after leaving the minor calyces, urine flows into the renal pelvis.

T F 14. The renal pelvis conveys urine outside the kidney proper.

628. Specify significant features of the ureters.

The Ureters. The ureters are two hollow, musculomembranous tubes which join with the renal pelvis and extend to the postero-inferior surface of the urinary bladder. These structures are 28 to 34 cm long, are of variable diameter, and are comprised of abdominal and pelvic portions.

Juncture of the distal renal pelves and the proximal ureters occurs in the region between and just anterior to the transverse processes of the first and second lumbar vertebrae. The *abdominal* portions pass downward, over the medial surfaces of the psoas major muscles, and behind the peritoneum, to the pelvic brim, and cross the wings of the sacrum just medial to the sacroiliac joints.

The *pelvic* portions of the ureters proper follow the general curvature of the pelvis. They curve forward and medially at about the level of the ischial spines, pass through the peritoneum, and join the urinary bladder in the region of the trigone. Figure 2-1 illustrates the ureters proper in relation to the kidneys, vertebral column, pelvis, and urinary bladder.

Each ureter is comprised of three layers or coats: (1) a fibrous coat, (2) a muscular middle coat, and (3) an inner mucous coat. The fibrous layer [(1) above] is continuous with the renal tunic which forms the floor of the renal sinus. The muscular middle coat [(2) above] is itself formed by three layers of muscle tissue. The outer muscle layer is made up of longitudinal fibers, the middle layer of circular fibers, and the inner layer of fibers that are generally longitudinal in direction. This muscular structure [(2) above] is quite similar to that found in the alimentary tract and is responsible for ureteral peristalsis. The mucosal inner coat [(3) above] extends from the renal papillae, which it surrounds, to the mucous membrane lining of the urinary bladder, with which it is continuous.

Exercises (628):

1. Each ureter is about how many centimeters long?

2. What are the names of the two portions of the ureters?

3. Where do the renal pelves join with the ureters?

4. What ureteral portion passes through the peritoneum?

5. Which ureteral layer is responsible for ureteral peristalsis?

6. What types(s) and arrangements of tissue comprise the layer or coat suggested in exercise number 5 above?

629. Provide structural details of the bladder and urethra.

The Bladder. The "storage area" of the urinary system is formed by the urinary bladder. This structure is a hollow, musculomembranous sac located in the lower, anterior portion of the true pelvis.

Naturally, the precise location of the bladder will vary in accordance with the amount of fluid it contains. Generally speaking, the inferior portion is situated behind the symphysis pubis; while the entire bladder is anterior to the rectum, and underneath the peritoneum.

The urinary bladder wall is comprised of an external serous coat, three layers of muscle tissue, a submucous coat, and a mucous-membrane lining. The outer layer of muscle tissue is comprised of longitudinal fibers, the middle layer of circular fibers, and the inner layer of still more longitudinal fibers. This muscular arrangement allows for free expansion of the bladder during the filling process. As the bladder fills, the superior surface rises into the abdominal cavity rounding off the posterior and lateral borders. As a rule, the bladder is considered moderately full when it contains 500 cc of urine. (However, in certain cases 2,000 cc, and more, have been removed from the bladder. This experience illustrates the expansive abilities of the urinary bladder.) The mucosa consists of loose folds (similar to the rugal folds of the stomach), which allow this membrane to stretch as the muscular walls expand. The urinary bladder and its component structures are depicted in figure 2-4 .

The trigone is a triangular area in the postero-inferior bladder wall. Its structure is basically the same as that described for the remainder of the bladder, but the musculature is not as expansive as is that of other segments of the bladder wall, and the mucosal lining is always smooth. The distal ends of the ureters pierce the wall of the trigone in the upper, outer regions, pass through the tissue on an inferomedial course for about 2 cm, and terminate in the *ureteral orifices.* When the bladder is empty, these openings are about 2.5 cm apart, but when the sac is full, they are about 5 cm apart. This fact illustrates the degree and direction of trigonal expansion. As the trigone stretches with the remainder of the bladder during filling, its musculature tightens on the distal ureteral ends, thus clamping them off and preventing regurgitation, or reflux, of urine into the ureters. The trigone also houses the internal urethral orifice. This crescent-shaped aperture is located in the apex of the trigone, which forms the most inferior portion of the bladder. The circular muscle fibers of the floor of the bladder are concentrated around the internal urethral orifice, thus forming the *internal urinary sphincter*. This layer of concentrically arranged muscle fibers contracts to close the urethral orifice, and on relaxation opens it.

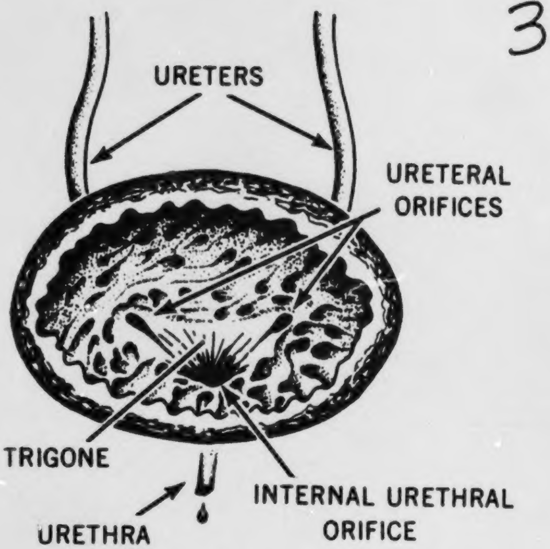

Figure 2-4. The urinary bladder.

The Urethra. The urethra is a hollow, narrow tube which extends from the bladder to the external surface of the body. The male urethra is about 20 cm (8 inches) long and is comprised of *prostatic*, *membranous*, and *cavernous* portions. The prostatic urethra is the widest and most dilatable portion of the tube. It extends downward for about 3 cm and passes through the prostate gland. This gland lies directly below and close to the external surface of the bladder floor. The membranous portion of the urethra is the shortest and least dilatable segment of the tube. It extends antero-inferiorly from the under surface of the prostate to the bulb of the urethra, a distance of about 1.25 cm. The cavernous portion of the urethra, usually about 15 cm in length, extends from its juncture with the membranous segment, through the penis to the external urethral orifice. It first passes upward to the front of the symphysis pubis, and then downward through the penis.

The female urethra is much shorter and straighter than that of the male. It extends from the internal urethral orifice downward and forward, for a distance of about 4 cm (1½ inches). As a rule, the female urethra is of uniform diameter and, since it is imbedded in the anterior vaginal wall, is relatively immovable.

Exercises (629):

1. What relationship exists between the location of the bladder and the symphysis pubis and rectum?

2. What four components or coats comprise the wall of the bladder?

3. How does the bladder accommodate increases in volume?

4. What is the trigone?

5. What is the difference between the musculature of the trigone and other bladder walls?

6. Where do the ureters enter the bladder?

7. Explain what occurs and when to prevent reflux of urine into the ureters.

8. What is the third opening into the trigone?

9. What function does the internal urinary sphincter serve?

10. Name the three portions of the male urethra.

11. What gland lies directly below the male bladder floor?

12. What is the longest portion of the male urethra?

13. About how long is the female urethra?

2-2. Reactions to Contrast Media

As you know, there is danger of your patient reacting to the contrast media injected into his bloodstream. The reaction may be mild with little or no consequences, or it may be severe and result in death. We include our discussion of reactions in this portion of the CDC because in most radiology departments, the intravenous pyelogram (IVP) is the examination most commonly performed in which reaction is possible. Keep in mind however that a reaction may occur anytime contrast media is injected into the patient.

Our study of reactions begins with a look at the signs and symptoms of different types of reactions. After that, we will discuss the emergency tray and some specific emergency items.

630. Indicate important factors associated with the detection and evaluation of reactions to injections of contrast media.

Detection and Evaluation of Reactions. The signs and symptoms that may be exhibited by the patient during or after the injection of a contrast medium vary, depending upon the type and severity of the reaction. Your primary concern is to be able to recognize a possible serious reaction and advise your radiologist immediately so that *he* can begin treatment. Of course, if the patient reacts to the contrast medium during the injection, your radiologist is present to evaluate the patient's condition because he, the radiologist, makes the injection. However, once the injection is finished, your radiologist normally returns to his office, leaving you to observe the patient while performing the radiographs. Now, let's look at how the signs and symptoms vary according to the type of reaction.

Technique reactions. Local signs and symptoms—that is, those located at or near the injection site—are sometimes referred to as *technique* reactions. For example, pain at the injection site is sometimes caused by infiltration of the contrast material into the tissues adjacent to the blood vessel. The infiltration, or extravasation as it is sometimes called, is quite painful and can last for 10 or

15 minutes until the contrast material is absorbed and removed from the area. Infiltration of blood can also cause pain at the site, but it usually is not as painful as the infiltration of the contrast material. Either type of infiltration can cause a noticeable elevation of the skin or "hematoma." Burning and numbness at the site of injection or along the upper arm are also considered technique reactions and disappear within a few minutes. Technique reactions, such as these described are usually not serious in nature.

Hemodynamic reactions. A reaction is said to be *hemodynamic* if it is precipitated by the movement involved in circulation of the blood. Some of the hemodynamic reactions may be temporary in nature, subsiding after a few seconds or a few minutes, and others may be severe enough to endanger the patient's life. The important point to remember is that the mild reactions may be initial manifestations of more severe reactions. Therefore, just because you have seen these mild reactions subside in the past, do not assume that they are not important. Two mild reactions are a feeling of warmth and flushing (redness of the face and neck). These *usually* disappear quickly. More severe cardiovascular hemodynamic reactions include an increase in blood pressure (hypertension), a drop in blood pressure (hypotension), weak rapid pulse, irregular pulse, or in case of cardiac arrest, no pulse at all. Others are cyanosis and unconsciousness.

Anaphylactic reactions. Anaphylactic reactions result when the patient is allergic to the contrast medium. As with hemodynamic reactions, they can be mild or severe. Also, mild reactions are initial manifestations of the more severe reactions. Signs and symptoms of anaphylactic reactions include urticaria (hives), which are elevated patches on the skin that are more red or more pale than the surrounding skin. Generalized itching also may occur, which may or may not be accompanied by urticaria. Tightness in the chest, sneezing and wheezing (audible breathing) also may be present.

Breathing difficulties or irregularities may be present—such as labored breathing, and high or low respiration rates. Also, breathing may cease altogether. Watery or reddened eyes are two other signs of anaphylactic reactions.

Other reactions. Nausea with or without vomiting may occur after injection of the contrast medium. Anxiety, headache, dizziness, and trembling may also be present.

Evaluation of reactions. As mentioned before, your radiologist initiates treatment if it becomes necessary during a reaction. We also mentioned that your radiologist may not be in the room when a reaction occurs. This leaves you with the decision of when to notify him or whether or not to notify him at all because, as mentioned before, some of the reactions are of brief duration. Unfortunately, there are no concrete answers to these questions. We can say that if such signs and symptoms as urticaria, hypotension, hypertension, difficulty in breathing, abnormal pulse, cyanosis, or equally severe reactions occur, you should notify him immediately. But whether you should notify him the instant your patient sneezes or has a mild technique reaction is something you should work out with him. He may want to be called if the patient exhibits *any* sign or symptom of a reaction. In any event an initial mild sign or symptom should alert you to the fact that a more severe reaction may be imminent, and you should observe the patient more closely for following events.

Exercises (630):

1. What is your primary concern associated with reactions to contrast media?

2. What type of reaction is caused by infiltration of contrast material or blood into the surrounding tissues?

3. Name four signs or symptoms that are shown by the patient during a reaction of the type indicated by exercise number 2 above.

4. Is a hemodynamic reaction always serious in nature? Is it always mild in nature?

5. Warmth and flushing are two mild hemodynamic reactions. Give their possible relationship to more severe reactions.

6. List seven serious hemodynamic reactions.

7. List ten anaphylactic reactions.

8. Briefly discuss the question of whether, and when, you should notify your radiologist of the patient's condition if he is reacting to the contrast medium.

631. Give the important guidelines for establishing and maintaining an emergency tray.

Emergency Equipment. Every radiology department using injectable contrast media must have on hand the appropriate equipment to treat a severe reaction. Usually called an *emergency tray*, the specific items of equipment are decided by your radiologist, and we discuss some of them later; however, there are significant features of the tray itself that we should discuss.

The emergency tray. First of all the equipment should be assembled on a single cart with rollers. The reason for having everything together is so that it is readily available. Remember, you cannot afford to waste time looking for a drug or laryngoscope when the need arises. (NOTE: If your radiologist elects to use some of the larger items, such as a large oxygen cylinder or a portable suction apparatus (also on rollers), obviously you cannot assemble these items on a single cart. The important issue is that you should assemble everything *possible* together.) The cart should have rollers so that it can be easily moved from one room to another, depending upon where the injection takes place.

The equipment should be placed neatly and orderly on the cart so that each item can be quickly located. One good way to accomplish this is to secure a piece of some type of foam rubber, at least 2 inches thick, on the top shelf of the cart. Then cut out depressions in the material to correspond with the sizes of your small items, such as syringes, needles, drugs, etc. Thus these small items remain in the same location on the cart, permitting quicker location when needed. Also, you can quickly spot a missing item during your *daily* inventory. Large items of equipment, such as the AMBU and intravenous fluids, can be placed on the bottom shelf of the cart.

As previously suggested, the emergency equipment should be inventoried daily to insure that the necessary items are available. Preferably, the inventory should be conducted the first thing in the morning before any examinations are started. At the time of inventory, the expiration date should also be checked on such items as locally assembled packs, drugs, etc. Also, you should test such items as the laryngoscope light (batteries don't last forever), the suction apparatus (plug it in and check for suction at the end of the hose), and the amount of oxygen remaining in the bottle.

You should attach to the cart a list of the items available so that someone unfamiliar with the contents can quickly determine if a particular item is available. The list can also serve as a checklist for inventory/inspection procedures.

One final word about the emergency cart: insure that everyone involved knows: (1) what items are available and (2) where they are located. Remember, *speed* in locating the proper item is essential during a severe reaction.

Exercises (631):

1. Why should your emergency items be assembled together in one specific location?

2. Why should your emergency items be assembled on a cart with rollers?

3. Why should specific items be arranged neatly and orderly on your emergency tray?

4. How often should your emergency items be inventoried?

5. In addition to checking on the availability of items, what other checks should the inventory include?

6. Why is it important that all personnel be familiar with the specific emergency items available and their precise location?

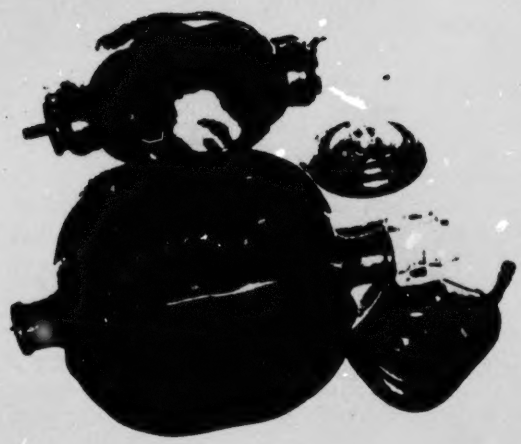

Figure 2-5. Pediatric and adult AMBU resuscitators.

632. Indicate the purposes and use of the AMBU and laryngoscope.

Specific equipment. As previously mentioned, your radiologist decides what items of equipment are included in your emergency setup. However, some items are typically required in most departments.

a. The AMBU resuscitator, shown in figure 2-5, is commonly included in an emergency tray. The resuscitator is available in both pediatric and adult sizes. It is used to provide air or oxygen to patients if spontaneous breathing stops or if breathing is difficult. The steps for using the AMBU are as follows: (NOTE: You should not attempt to use equipment, such as the AMBU until you have received sufficient on-the-job training and then only as part of a preconceived plan with your radiologist.)

(1) Tilt the patient's head back and lift his jaw forward.

(2) Hold the mask firmly against his face with your thumb and index finger, keeping his chin and head back with your other three fingers.

(3) Inflate his lungs by squeezing the bag with your other hand. Watch his chest rise.

(4) Release the bag and let the patient exhale. The bag will automatically fill for the next inflation. Repeat every three seconds—one second for inhalation—two seconds for exhalation.

The patient can receive oxygen through the AMBU as well as room air. Simply connect an oxygen hose to the input nipple located at the end of the bag. Obviously, you must insure beforehand that you have an oxygen hose that will fit the nipple. The AMBU suction pump, shown in figure 2-6, is supplied with the resuscitator. It is used to remove blood, mucus, or other similar material from the air passage. Operation of the pump itself is relatively simple. You will need a catheter (not supplied with the pump) to attach to the adapter end of the hose that leads to the collection bottle. *You* do not insert the catheter into the patient, but you can operate the pump simply by depressing the bellows one-third to one-half the way down with your foot. Maintain a constant rhythm with your foot.

b. Sometimes during a severe reaction the patient's larynx closes, and the patient cannot breathe. When such is the case, an anesthetist or physician must insert an endotracheal tube through the mouth into the trachea. The endotracheal tube is inserted with the use of a laryngoscope. The laryngoscope is a device consisting of a detachable blade mounted on a battery-containing handle. Also included is a small bulb which permits the physician to see the laryngeal area. As a rule, once the endotracheal tube is inserted, resuscitation is performed with the AMBU. The mouthpiece of the AMBU slips off so that the opening can be fitted to an adapter that connects the AMBU to the endotracheal tube. Be sure to have such an adapter available, along with various sizes of laryngoscope blades and endotracheal tubes.

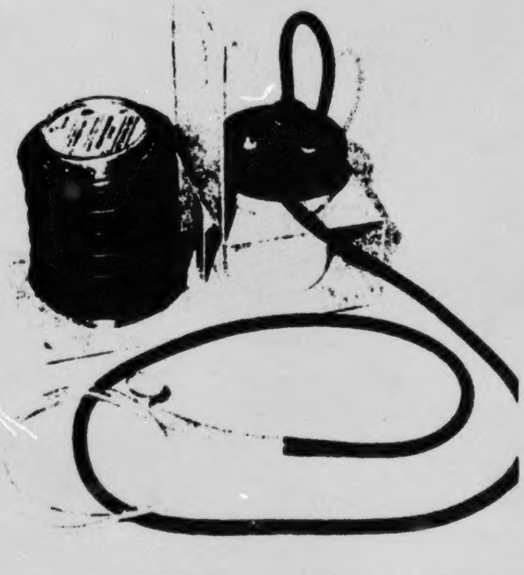

Figure 2-6. AMBU foot-operated suction pump.

Exercises (632):

1. What is the purpose of an AMBU?
2. Under what conditions should you use an AMBU?
3. Explain the procedure for using an AMBU.
4. How is oxygen administered through an AMBU?
5. What item of equipment (not supplied) is needed to use the AMBU suction pump?
6. How should the bellows of the AMBU suction pump be operated?
7. Give one use of a laryngoscope.
8. Why should your laryngoscope kit contain an adapter?
9. Should your laryngoscope kit have more than one blade and tube?

2-3. Radiography of the Urinary System

We now turn our attention to radiographic examinations of the urinary system. We include the following examinations: intravenous pyelography, cystography, and cystourethrography.

633. Show the dosage and alternate injection sites for an IVP performed on a child.

Intravenous Pyelography. The specific procedures involved during an IVP, like many other radiographic examinations vary from place to place. However, some aspects of the examination are common, and we discuss those as well as other less seldom used procedures.

Contrast medium dosage. The usual adult (14 years and older) dose of the contrast medium is 30 to 60 cc. For children under 14, the dose varies depending upon the patient's weight or age. Some contrast media manufacturers recommend 0.5 cc per kilogram (kg) of body weight. One kg equals 2.2 pounds. Consequently, if the patients's weight is 40 pounds, the dose is 9 cc because $\frac{40}{2.2} = 18$ and $18 \times 0.5 = 9$. Some manufacturers recommend a specific dose, depending upon the child's age. Usually the dose in either case is from 0.5 to 1.0 cc per kg of body weight. When preparing the medium for injection, prepare the amount requested by your radiologist. However, because he usually follows the recommendations of the manufacturer in the case of children, you should be prepared to provide him with the literature. Also, keep in mind that you must weigh the child in advance because scales are not usually available in the radiology department.

Administration of the contrast medium. At times (usually with small children) when the radiologist cannot inject the contrast medium into a blood vessel, he can introduce it subcutaneously over each scapula or intramuscularly into each gluteal muscle. As indicated, equal amounts of the medium are introduced into two sites. He may or may not mix the contrast medium with equal amounts of sterile water for injection.

Exercises (633):

1. The amount of contrast medium injected for an IVP on a ____________ is based upon his weight or ____________________.
2. If the patient's weight is used to determine the dosage, the dose usually ranges from ________ to ________ per ____________ of body weight.
3. If the manufacturer's brochure recommends 1.0 cc of contrast medium per kilogram of weight, a child weighing 50 pounds would receive ________ cc.
4. Where may the radiologist inject the contrast medium into a child other than into a vessel?

634. Provide pertinent facts about the importance of, and performance of, an IVP scout film.

Scout film. A scout film of the abdomen is always performed before the contrast medium is injected for an IVP. Before performing the scout, have the patient completely empty his bladder for two reasons: (1) It prevents dilution of the contrast material in the bladder and thereby allows better demonstration of the bladder, and (2) it reduces the possibility of rupturing the distended bladder if ureteral compression is applied.

The scout film serves several purposes. First of all, it allows the radiologist to determine whether or not the patient is adequately "cleaned out." If the patient has considerable gas and fecal material in his bowel, the examination may not be diagnostic, because the contrast medium in the urinary tract may be obscured. Secondly, it allows the radiologist to see a urinary tract stone or other abnormality that can be obscured by the contrast medium. The scout film also enables you to check your exposure and positioning and make the necessary adjustments on the subsequent radiographs. Centering the film is especially important during an IVP because you must include the superior portion of the symphysis pubis and the upper margins of the kidneys. This is usually not a problem with an average-sized individual. Simply center the 14 x 17 cassette to the iliac crests. However, on a large patient you may not be able to include the necessary anatomy on a single radiograph. This is where you can use the scout film to advantage. It may be necessary for you to center the 14 x 17 three or four inches higher than normal and use a 10 x 12 cassette centered 2 inches above the symphysis pubis to include the lower pelvis. Since this procedure obviously increases the patient's radiation dose considerably, be sure to check it out with your radiologist.

When performing the scout film and all other AP projections of the kidneys during an IVP, some radiologists prefer that you flex the patients' knees to place the lower back in contact with the table as you would for an AP lumbar spine. Also, he may want you to elevate the head and shoulders slightly on one or two pillows. By doing so, you place the long axes of the kidneys as near as possible parallel with the plane of the film and reduce their distortion on the radiograph.

Exercises (634):

1. Why should the bladder be emptied before performing an IVP scout film?

2. Briefly discuss the purposes of the IVP scout film.

3. What two upper and lower anatomical areas must you include on the IVP scout film?

4. How can you minimize distortion of the kidneys on the IVP scout film?

635. Answer key questions pertaining to the performance of IVP radiographs.

Other projections and procedures. Once the contrast medium is injected, various projections and procedures can be performed. Usually radiographs are made at timed intervals, beginning 5 minutes after the completion of the injection. Posterior obliques of the kidneys are sometimes performed at 10 or 15 minutes from injection, in which case you should use a 10 x 12 cassette crosswise. For the obliques, rotate the patient 25° to 30° and center the lower margin of the film 2 to 4 inches above the iliac crests. Obliques are also taken of the entire system, which of course indicates a 14 x 17 film instead of a 10 x 12. A postvoiding erect film is usually taken to check for gravitational emptying of the renal calyces and pelves and to evaluate the mobility of the kidneys. Also, a postvoiding AP projection of the bladder area is sometimes performed on males to reveal enlargement of the prostate gland and to check bladder retention of both sexes. Before voiding, provide the patient with a container covered with gauze if a urinary stone is suspected. The urine always should be strained in this case and if, after inspecting the gauze you find a stone, report it to your radiologist.

Some radiologists feel that they can better outline the renal pelves and calyces by compressing the ureters and thus restricting the flow of contrast material into the bladder. This purpose is accomplished by using compression across the upper pelvis at the level of the anterosuperior iliac spines. Compression is usually applied after completion of the injection and released at a specified time after one or more radiographs are made. A radiograph can also be made a few seconds after release of the compression to visualize the contrast-filled ureters. Compression can be applied in a number of ways although you usually use the compression band supplied with your X-ray unit. Some radiologists like to use a blood pressure cuff underneath the compression band. After the band is tightened until it is "snug" the cuff is inflated a specified amount, usually from 90 to 110 mm of mercury. Using a device, such as this is advantageous because the amount of pressure on the ureters can be repeated from one examination to another. You can also place a foam rubber pad or other positioning aid under the compression band and tighten the band to compress the ureters.

If the patient cannot tolerate the compression, and many patients cannot, the purpose of the compression can be partially satisfied by using the Trendelenburg position (10° to 20°). This position retards the flow of the contrast medium into the bladder due to the countereffects of gravity. When performing radiographs with the patient so positioned, be sure to angle the tube caudally the same degree to which the table is tilted to prevent distortion.

Exercises (635):

1. If you perform obliques of the kidneys, how many degrees should you rotate the patient?
2. Give two reasons for performing a postvoiding erect radiograph.
3. Why should a postvoiding radiograph be made of the bladder?
4. What patients should be instructed to strain their urine?
5. What advantages are realized by using compression before performing radiographs of the bladder area?
6. Where should the compression be applied?
7. Why is it advantageous to apply compression with a blood pressure cuff?
8. If a blood pressure cuff is used to apply compression, to what extent should the cuff be inflated?
9. If the patient cannot tolerate compression, what alternate procedure may be used to achieve the desired effect?

636. Specify the purpose of administering a carbonated beverage to a child receiving an IVP and the amount of beverage administered.

Pediatric intravenous pyelography. One of the problems associated with an IVP on a pediatric patient 8 years of age and under is that preparation of the gastrointestinal tract is difficult or clinically contraindicated. As a result, gas and fecal shadows can overlie the kidneys and obscure the contrast medium. This problem is easily solved by giving the patient a carbonated beverage which distends the stomach with gas. Distention of the stomach displaces the bowel downward so that it no longer overlies the kidneys. Also, the excellent contrast produced between the resulting gas bubbles in the stomach and the medium-filled kidneys provides even better demonstration of the kidneys than if the patient was properly prepared in the first place. Usually, 2 ounces of beverage is given to an infant and 12 ounces to a child 8 years old, with proportionate amounts for ages in between.

Exercises (636):

1. How does the ingestion of a carbonated beverage improve visualization of the kidneys during an IVP on a child?

2. How many ounces of carbonated beverage are given to children undergoing IVPs?

637. Indicate the purpose and general procedures used during a hypertensive IVP.

Hypertensive intravenous pyelography. A hypertensive IVP is performed to determine whether or not hypertension is caused by stenosis (narrowing) of a renal artery. If stenosis is present in a renal artery, excretion of the contrast material by the kidney of the affected artery can be delayed when compared with the opposite kidney. To evaluate the difference between the appearance and concentration of contrast material in the kidneys, the medium is injected rapidly into the vascular system, after which radiographs are taken at 30 second to 1 minute intervals for about 5 minutes.

Following the prescribed number of films, a "urea washout" study should also be performed. The study is accomplished by the infusion of a mixture of saline and urea, a substance which promotes the secretion of urine. Radiographs are made at 5 or 10 minute intervals to determine if the contrast material "washes out" of one kidney faster than the other.

Exercises (637):

1. What specific vascular abnormality may be indicated by a hypertensive IVP?

2. If the condition indicated in exercise number 1 is present, how could it be suggested on a hypertensive IVP?

3. At what relative speed is the contrast medium injected for a hypertensive IVP, and at what intervals are radiographs made?

4. What is a "urea washout"?

638. Given a list of statements pertaining to the performance of a cystogram and cystourethrogram, indicate which are true and which are false.

Cystography and Cystourethrography. Cystograms and cystourethrograms are made by the retrograde introduction of a negative or positive contrast medium into the bladder. (An incidental cystogram is obtained when an intravenous pyelogram is performed, but the amount and concentration of the contrast material is insufficient for a complete study.) The positive contrast medium used is either a diluted injectable urographic medium or a noninjectable medium made specifically for these studies. Oxygen, carbon dioxide, or air is used for the negative medium during a cystogram.

General considerations. The exact procedures for performing a cystogram or cystourethrogram vary. Most radiologists, however, monitor the filling phase to insure that the bladder is sufficiently filled but not overfilled. Some radiologists perform all films during fluoroscopy with spot films, cine, etc., while others film only the urethra in that manner and include "overhead" radiographs for the bladder. In either case, voiding films of the urethra are almost always performed under fluoroscopy.

Projections. Usually, you are required to perform several projections of the bladder during a cystogram. In all cases, center the film to the level of the soft tissue depression immediately above the most prominent point of the greater trochanter.

a. When performing the AP projection, extend the patient's legs to arch the lumbosacral spine. In this position the lumbosacral spine is arched and the pubic bones are tilted downward, which helps to project the symphysis pubis caudally and away from superimposition over the neck of the bladder. Also, for the same reason, angle the C.R. 5° caudally. If there is a loss of the normal lumbar lordosis when the patient's legs are extended, angle the C.R. 15° to 20° caudally. An additional AP projection is sometimes made to examine the distal ureters in case of reflux. Tilt the table so that the patient is in the Trendelenburg position—15° to 20°—and use a vertical C.R. In this position, the filled bladder moves superiorly and usually permits an unobstructed view of the distal ureters.

b. For the oblique projections, rotate the patient 40° to 60°, depending upon your radiologist's preference. These projections are taken to provide oblique views of the bladder proper and also to reveal reflux of the contrast medium into the distal ureters.

c. A PA projection of the bladder is sometimes made to project the prostate gland above the symphysis pubis. Angle the C.R. 20° to 25° toward the head. It should enter the patient about 1 inch distal to the tip of the coccyx and exit slightly above the symphysis pubis.

d. Lateral projections of the bladder are taken to demonstrate the anterior and posterior bladder walls.

e. The Chassard-Lapine projection described in chapter 1 of this volume is also occasionally used to demonstrate the posterior bladder wall and the distal ureters in case of reflux.

Chain cystourethrography. A chain cystourethrogram is sometimes performed on females to evaluate the anatomical relationships between the bladder, urethrovesical junction, urethra, and urethral orifice. One end of a metallic bead chain is introduced into the bladder while the other end remains outside taped to the patient's thigh. The bladder is also filled with a positive contrast medium. Usually, you will be required to make two radiographs an AP and a lateral—while the patient is performing Valsalva's maneuver and the same projections repeated without the maneuver. Most commonly the radiographs are taken with the patient erect.

Exercises (638):

Indicate whether the following statements pertaining to the performance of cystography and chain cystourethrography are true or false. If you indicate "false," you must explain your answer.

T F 1. The contrast medium may be negative or positive.

T F 2. Fluoroscopy is almost always used when making voiding films.

T F 3. Radiographs of the bladder should be centered to the level of the greater trochanter.

T F 4. Extension of the legs for an AP cystogram removes unwanted shadows from the area under examination.

T F 5. The C.R. should always be angled 15° to 20° caudally for an AP cystogram.

T F 6. An AP projection of the bladder with the patient in the Trendelenburg position—15° to 20°—may demonstrate the distal ureters.

T F 7. The C.R. for the projection in exercise number 6 above is perpendicular to the film.

T F 8. AP and obliques and Chassard-Lapine projections may reveal reflux into the distal ureters.

T F 9. If a PA prostate projection is made, the C.R. is angled 20° to 25° cephalic.

T F 10. Lateral and Chassard-Lapine projections demonstrate the posterior bladder wall.

T F 11. A chain cystourethrogram is performed to evaluate the anatomical relationships between the bladder and urethral structures.

T F 12. During a chain cystourethrogram, supine AP and lateral radiographs are usually made.

T F 13. Chain cystourethrographic projections usually are made with and without Valsalva's maneuver.

2-4. Anatomic and Radiographic Considerations of the Female Reproductive System

The last portion of the urogenital system we discuss is the female reproductive system. We begin with a look at the anatomy and then study hystero-salpingography.

639. Cite significant features of the female reproductive system.

Anatomic Considerations. Generally, the female reproductive system consists of two groups of structures—internal and external—connected by the vaginal canal. Our discussion is mostly centered around the internal structures, including the vagina, uterus, fallopian tubes, and ovaries. Refer to figures 2-7 and 2-8 as we discuss them.

Vagina. The vagina is a musculomembranous tube that connects the external structures to the uterus. It extends superiorly and posteriorly to a point where it meets the inferior portion of the uterus. The vagina lies between the rectum and the urinary bladder.

Uterus. The pear-shaped uterus is a hollow, thick-walled structure situated in the pelvis cavity between the rectum and the urinary bladder. It consists of the cervix, which is its

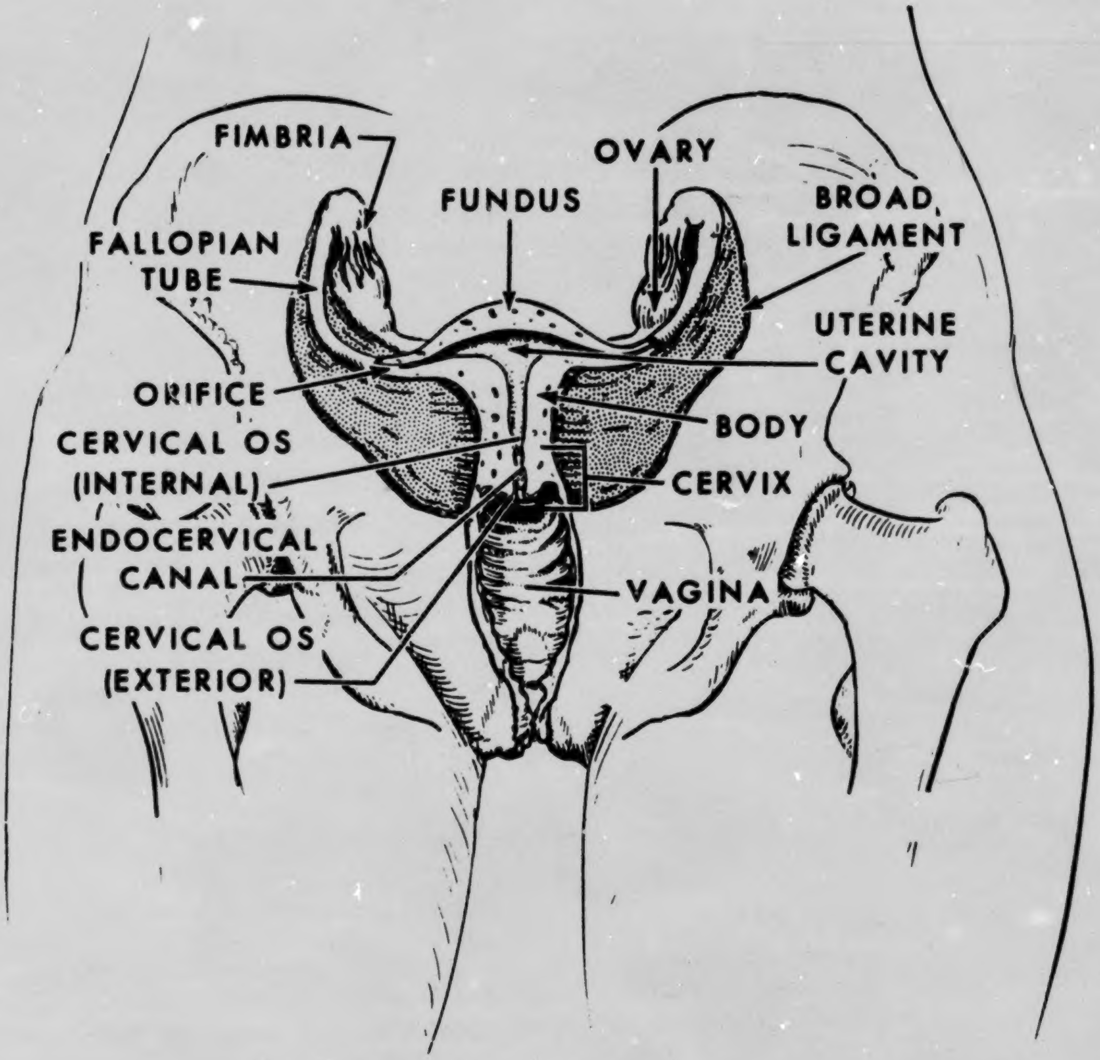

Figure 2-7. Female reproductive system.

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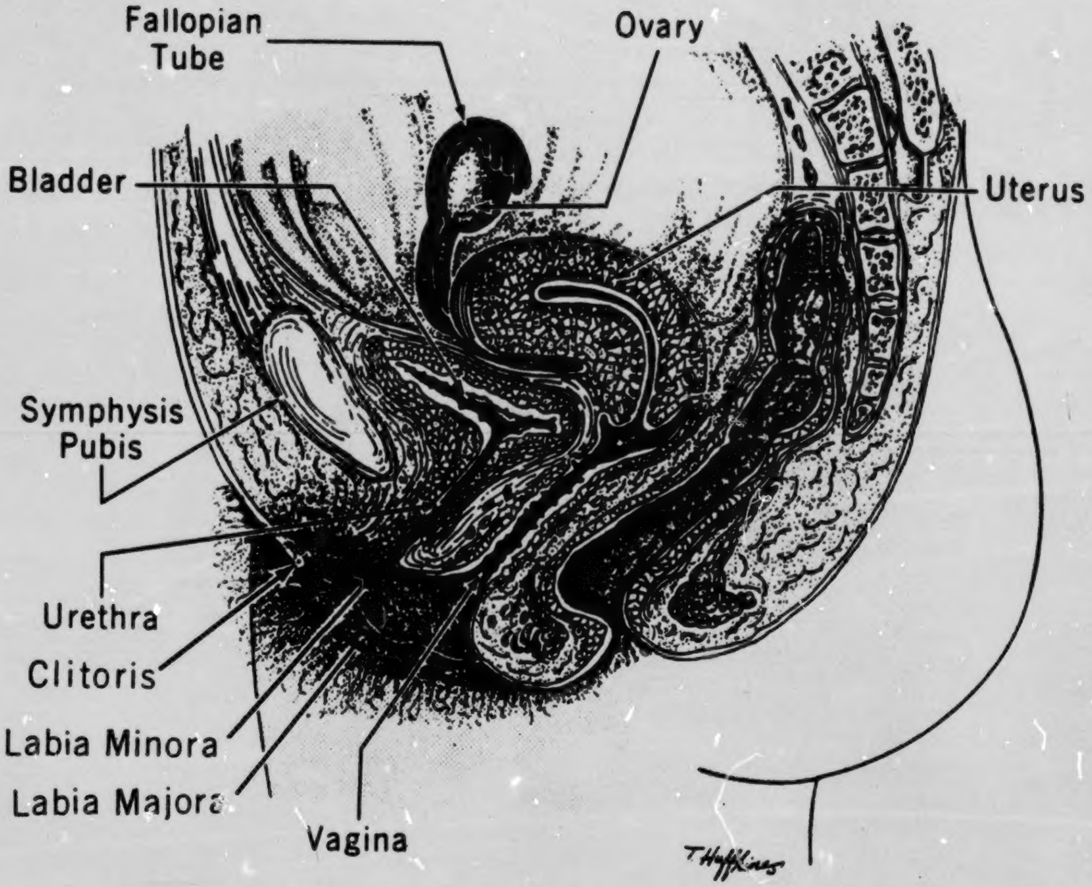

Figure 2-8. Internal structure of the female reproductive system.

narrow, interior end; the corpus or body, which comprises the major bulk of the organ; and the fundus, which is its curved superior position. The uterus is usually tipped anteriorly, with its anterior surface close to the posterior and superior aspects of the bladder. The cervix extends into the vagina and contains the external cervical os in its distal surface. The small opening communicates with the endocervical canal, which passes through the muscular cervix and joins with the uterine cavity by means of the internal cervical os. Two small orifices represent the uterine openings of the fallopian tubes. They are housed in the upper, lateral aspects of the body. The fundus forms an oval roof and is situated above the level of the orifices.

The fallopian tubes. The fallopian tubes, also called the uterine tubes or oviducts, are hollow, musculomembranous structures which extend laterally from the uterus to the ovaries. They are about 12 cm long and lie along the leading edge of a broad ligament that supports the uterus. Their lateral ends consist of several irregular projections called fimbria, which surround the ovaries.

The ovaries. The ovaries are the primary reproductive organs of the female system. These almond-shaped organs are located on either side of the uterus below the fallopian tubes. They are about 4 cm long, 2 cm wide, and 8 mm thick. The ovaries are comprised of a central framework of vascular tissue that houses numerous ovarian follicles. These follicles serve as containers for the ova, or eggs, and appear in varying stages of maturity.

Exercises (639):

Fill in the blank spaces with one appropriate word.

1. The vagina and uterus are located between the urinary bladder and __________.
2. The upper curved portion of the uterus is the __________.

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3. The opening of the fallopian tubes into the uterus occurs in the upper __________ aspects of the __________.

4. The fallopian tubes extend __________ from the uterus and are about __________ cm long.
5. Several __________, make up the distal ends of the fallopian tubes and surround the __________.
6. The almond-shaped ovaries are approximately ________ cm long, ______ cm wide, and __________ mm thick.

640. Indicate the purpose and procedures used for a hysterosalpingogram and a Rubin's test.

Radiographic Considerations. While hysterosalpingography is performed for other reasons, it is usually done to determine whether or not the fallopian tubes are patent (open or unobstructed). Patency of the tubes is evaluated as part of a sterility "workup." If the tubes are patent the positive contrast medium passes through them and "spills" into the peritoneal cavity and visualizes as such on the radiographs.

Aside from a hysterosalpingogram, a Rubin's test is sometimes conducted by the gynecologist to determine patency of the fallopian tubes. Usually performed in the gynecology department, carbon dioxide is introduced into the tubes under pressure and patency is determined by the amount of resistance. If the tubes are open the carbon dioxide, like the positive contrast medium, spills into the peritoneal cavity. Sometimes the gynecologist elects to document the presence of air in the peritoneal cavity with a radiograph. You should perform a routine erect PA chest or erect AP abdomen to include the diaphragms just as you would to demonstrate "free air" under any other circumstances. Since the carbon dioxide is absorbed rather quickly, you should perform the radiograph as soon as possible.

Patient preparation. A hysterosalpingogram is usually performed 7 to 8 days after completion of menstruation. The colon may or may not be cleared of gas or fecal material on the evening before, or the day of, the examination, depending upon the preferences of the radiologist and gynecologist. In any event, have the patient void before she assumes her position on the X-ray table to reduce the possibility of a filled bladder impinging upon the fallopian tubes. The filled bladder may also present an extraneous dense shadow which might interfere with visualization of the contrast medium.

Preparing for the examination. If an oily contrast medium is used for the examination, it should be warmed to body temperature so that it will flow more freely. One major consideration to keep in mind is that when the contrast medium is injected into the uterus and fallopian tubes, it is done so under considerable pressure, which causes the patient a lot of pain. After you perform the radiographs, the gynecologist removes the pressure, which relieves the pain. It follows that you should perform your radiographs as quickly as possible. For this reason, we recommend that two technicians perform the radiographs to save time. Precisely which technician does what during the examination is something you should decide as long as you minimize the time required to perform the radiographs.

For the same reason mentioned above, you should assemble the necessary cassettes with the identification markers (R, L, CCs, etc) already taped on the cassette. Changing these markers between radiographs is inexcusable in this case because you are actually prolonging the patient's discomfort.

Performing the radiographs. As a rule, only AP and posterior oblique projections are performed during a hysterosalpingogram. Use 10 x 12 inch cassettes crosswise, centered to a point 2 inches superior to the symphysis pubis. A delayed AP projection (up to 24 hours) is sometimes made to check for spillage if it is not present immediately.

Exercises (640):

1. Why is a hysterosalpingogram usually performed?

2. Why is a Rubin's test performed?

3. If a patient arrives in the radiology department for a radiograph immediately after a Rubin's test, what is the likely reason for the film and what radiograph should you make?

4. Why should the patient void before a hysterosalpingogram?

5. Why should an oily contrast medium be warmed to body temperature before a hysterosalpingogram?

6. How can you minimize the period of time the gynecologist maintains the pressure injecting the contrast medium and consequently the patient's discomfort?

7. Where should you center the film for the hysterosalpingographic projections?

CHAPTER 3

Contrast Study of the Respiratory System

AS YOU KNOW, the chest is perhaps more frequently X-rayed than any other portion of the body. While most abnormalities of the chest are evaluated by standard radiography, it is necessary at times to introduce a contrast medium into the lungs to better visualize the structures via bronchography.

We begin our study of the respiratory system with a close look at the anatomy involved. After that, we examine the various methods used to introduce the contrast medium, and finally the procedures involved in the bronchogram itself.

3-1. Anatomic Considerations of the Respiratory System

In this discussion, we examine the anatomy of the respiratory system from the larynx to the alveolar sacs.

641. Provide information about significant features of the larynx, trachea, and primary bronchi.

Larynx. The *larynx* (see fig. 3-1), sometimes called the voice box, is located in the upper anterior portion of the neck extending from the fourth to the sixth cervical vertebrae. It serves as a passage of air between the oropharynx and the trachea and is located immediately anterior to the laryngeal pharynx. The larynx is suspended from the hyoid bone and is made up of various structures including the *thyroid* and *cricoid* cartilages. The *epiglottis* guards the entrance of the larynx, preventing food from entering the trachea during the act of swallowing.

Trachea. The trachea (see fig. 3-2) is often called the windpipe. It is a rounded cartilaginous tube about 4½ inches long and is located in front of the esophagus. It extends from the larynx to the level of the superior border of the fifth thoracic vertebra, where it bifurcates into the right and left main bronchi. The internal walls of the trachea are lined with mucosa. The innermost surface of this mucosa is composed of stratified, ciliated epithelium, while its deeper portion is composed of a looser meshwork of connective tissue containing the mucous glands, nerves, and blood vessels. The mucosal cilia, along with the mucous secretions, filter any inhaled dust particles and move them upward to the pharynx. The external surface consists of partial, C-shped cartilaginous rings, embedded in fibrous tissue to give the trachea its rigidity. The C-shaped rings open posteriorly, leaving gaps which are covered by strips of muscular tissue to form a flat posterior surface where the trachea overlies the esophagus.

Primary Bronchi. At its inferior aspect, the trachea branches into two smaller tubes—the right and the left primary bronchi—which are similar in construction to the trachea. One bronchus goes to the right lung, the other to the left.

Right bronchus. The right bronchus consists of from six to eight cartilaginous rings which are smaller than, but otherwise identical to, those of the trachea. It enters the right lung at the level of the fifth thoracic vertebra. It is shorter, wider, and more vertical in position than the left bronchus.

Left bronchus. The left bronchus is smaller in diameter and longer than the right

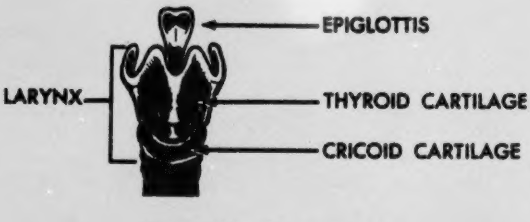

Figure 3-1. The larynx.

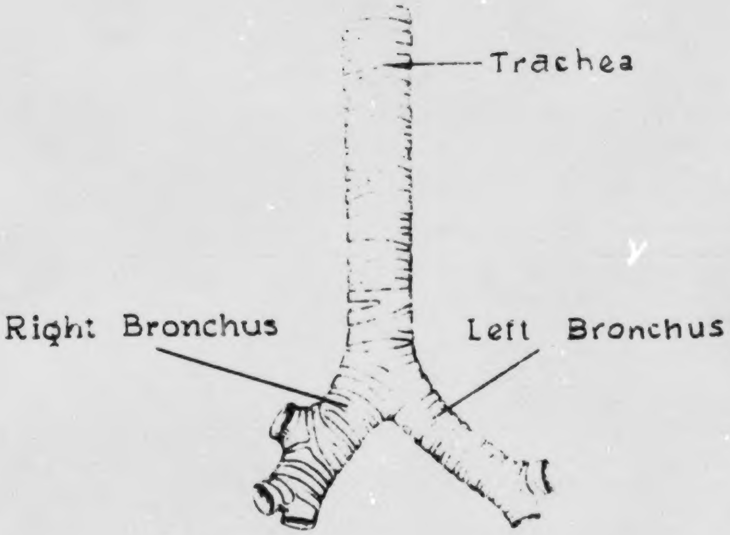

Figure 3-2. The trachea and main bronchi.

bronchus. It has from 9 to 12 cartilaginous rings, and enters the left lung at about the level of the sixth thoracic vertebra. Figure 3-2 illustrates the primary bronchi.

Exercises (641):

Fill in the blank spaces below with one appropriate word.

1. The larynx serves as an air passage between the oropharynx and the _____________ .
2. Two major cartilages that make up the larynx are the __________ and the _____ .
3. The entrance to the larynx is guarded by the _______________ .
4. The trachea is located __________ to the esophagus.
5. The trachea bifurcates at the level of the __________ thoracic vertebra.
6. Inhaled dust particles are filtered in the trachea by the mucosal __________ and mucous ___________ .

7. The rigidity of the trachea is provided by C-shaped __________ which open _____.
8. The trachea divides into the ______________ and ______________ primary bronchi.
9. The ___________primary bronchus enters the ___________ lung at a slightly lower thoracic level than does the __________ bronchus.

642. Indicate the anatomical structures and physiological features of the bronchial tree.

The Bronchial Tree. The main bronchi bifurcate within the lungs to form the bronchial tree. You can relate the textual descriptions to the illustrations in figure 3-3.

Secondary bronchi. The first branch from the primary bronchi is the *secondary*, or

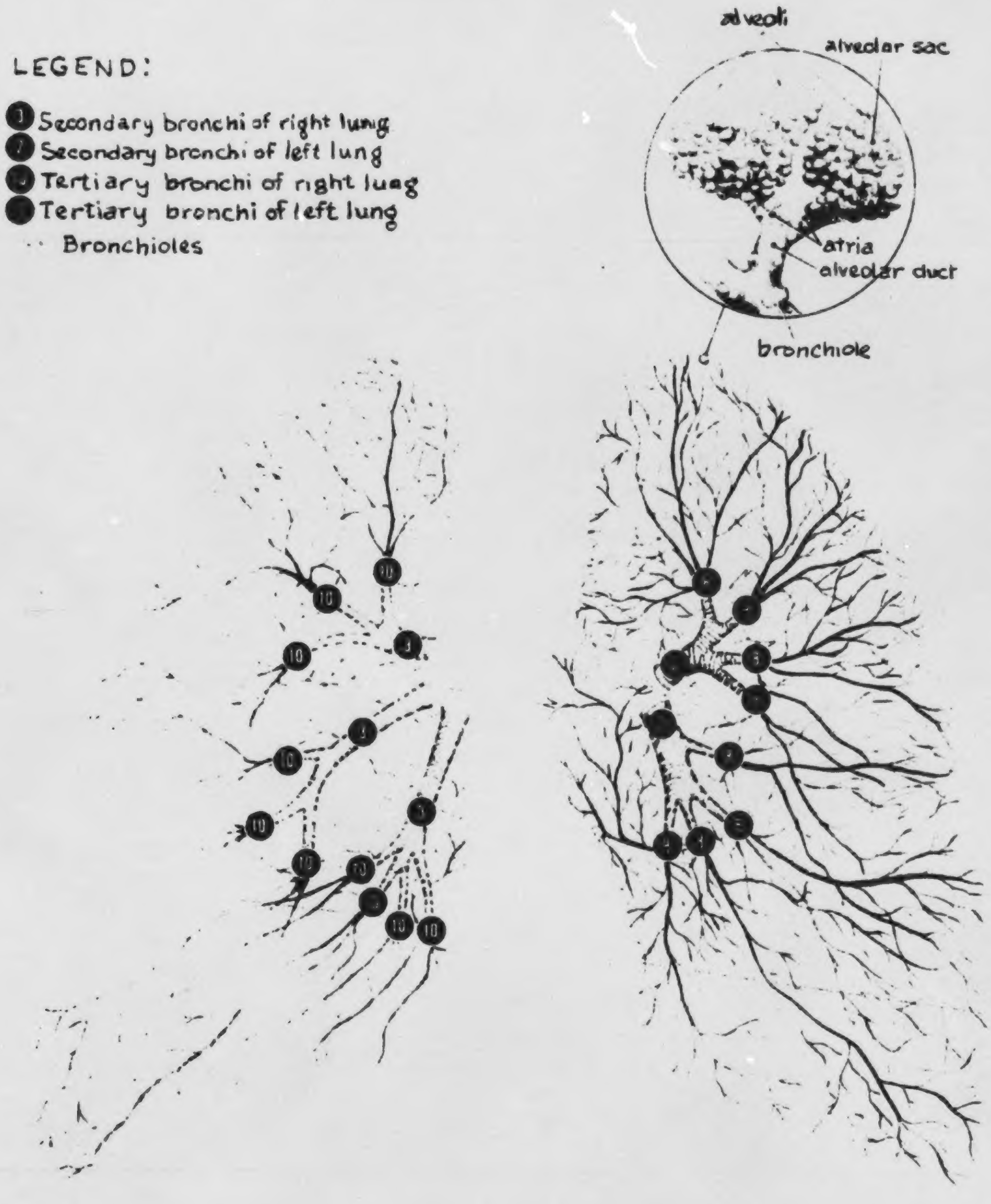
LEGEND:
● Secondary bronchi of right lung
● Secondary bronchi of left lung
● Tertiary bronchi of right lung
● Tertiary bronchi of left lung
·· Bronchioles
alveoli
alveolar sac
atria
alveolar duct
bronchiole
10
10
10
10
10
10
10
10
10

Figure 3-3. The bronchial tree.

lobar, bronchi. The right lung has three secondary bronchi, the left has two. There is one secondary bronchus for each lobe.

Tertiary bronchi. The secondary bronchi are further divided into *tertiary*, or segmental, bronchi. The right lung usually contains 10 tertiary bronchi, one for each bronchopulmonary segment. The left lung has eight tertiary bronchi and eight bronchopulmonary segments.

Bronchioles. Next in order of subdivision are the *bronchioles* (little bronchi) *which* enter the lung tissues. To this point, the bronchi and their subdivisions are composed of fibrous tissue and resemble the C-shaped cartilaginous rings of the trachea and the primary bronchi. But when the bronchi becomes bronchioles, their diameter is decreased to 1 mm or less and the cartilage is no longer seen. Each bronchiole penetrates deeper into the lung tissue, where it divides into several ducts called the alveolar ducts.

Atria. Next in the subdivision are the *atria*, which are irregularly shaped, elongated air sacs continuous with the alveolar ducts. From the atria, the alveolar sacs continue the subdivisions.

Alveoli. Finally, the *alveoli* are reached. These are minute, cup-shaped air cells that project from the walls of the bronchioles, alveolar ducts, atria, and alveolar sacs, and which become more numerous at the terminal portion of the respiratory system. They consist of a very delicate, thin layer of epithelial tissue and are surrounded by a network of capillaries. It is here, where the alveoli are close to the bloodstream, that the gases are exchanged through diffusion.

Exercises (642):

1. How many secondary branches are in the left lung? In the right lung?

2. What is another name for the secondary bronchi?

3. What is the next subdivision after the secondary bronchi?

4. At what point do the C-shaped cartilaginous rings of the bronchi cease to exist?

5. What ducts appear immediately after the bronchioles?

6. From what pulmonary structures does the exchange of gases occur in the lungs?

643. Name, locate, and show significant features of the lungs.

The Lungs. The lungs, shown in figure 3-4, are located on both sides of the mediastinum, where they occupy the right and left portions of the thoracic cavity. Each extends from about 1 to 1½ inches above the clavicle to the superior border of the diaphragm. They are separated from each other by the *mediastinum*, which contains the heart, esophagus, part of the trachea, the great vessels, primary bronchi, and many other smaller structures. The root of each lung connects the lung, trachea, and heart and contains the pulmonary artery and vein, bronchus, bronchial arteries and veins, nerves, lymphatics, and lymph nodes. The arteries, veins, and nerves enter and leave the lung at a point called the *hilum*, a triangular depression on the inner medial surface of each lung.

The lungs are composed of a light, porous and spongy, elastic tissue. Each resembles an inverted cone in shape and consists of an apex, base, costal and mediastinal surfaces, lobes and fissures, and a bronchial tree. The apex is rounded and extends to about 1 to 1½ inches above the level of the sternoclavicular joints, bilaterally.

The lung base, or diaphragmatic surface, consists of a broad, concaved, inferior part that rests on the convex superior surface of the diaphragm. Because it covers the right lobe of the liver, the base of the right lung has a deeper concavity than the left.

The interlobar (oblique) fissure divides the left lung into two parts—a superior (upper) lobe and an inferior (lower) lobe; the latter is the larger of the two. The right lung has three lobes. An interlobar fissure, similar to that of the left lung, separates the inferior lobe from the middle and superior lobes. A horizontal fissure at the level of the fourth costal cartilage makes a wedge-shaped middle lobe between the inferior and superior lobes.

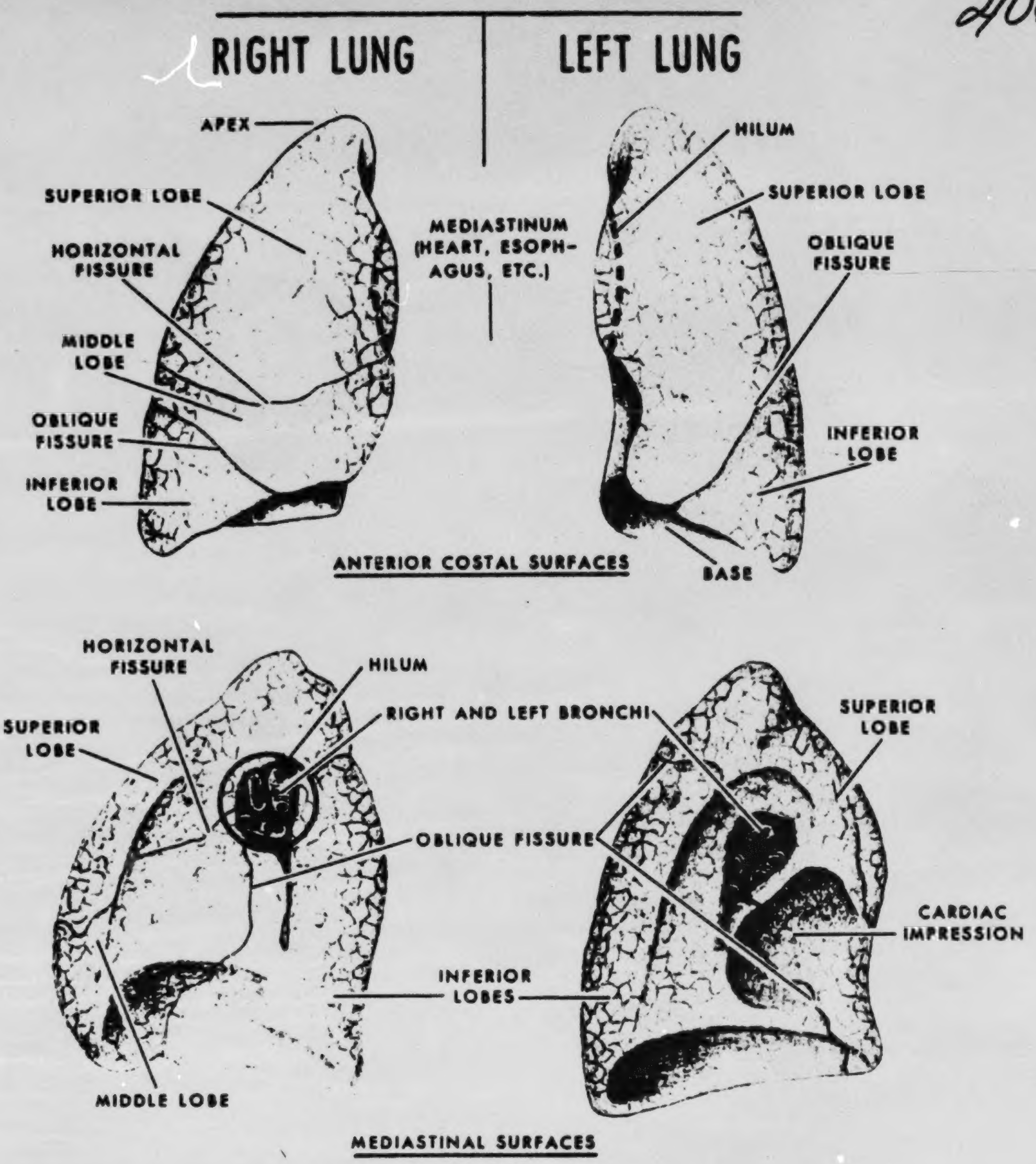

Figure 3-4. The lungs.

Exercises (643):

1. What is the name of the area between the lungs?

2. What is the hilum?

3. Where is the apex of a lung located?

4. On what structure does the base of the lung rest?

5. How many lobes has the right lung? The left?

6. What structures mark the divisions of the lobes of the lungs?

3-2. Methods of Introducing the Contrast Medium

There are at least four methods for introducing the contrast medium into the lungs for a bronchiogram. The particular method used depends primarily upon the personal preference of the radiologist and the age and condition of the patient. The four methods are: (1) intratracheal intubation, (2) supraglottic, (3) intraglottic, and (4) cricothyroid.

644. Differentiate between the four methods of introducing the contrast medium during a bronchogram.

Intratracheal Intubation Method. The intratracheal intubation method is perhaps the most commonly used method for introducing the contrast medium into the lungs. The tube or catheter is inserted either through the mouth or, most commonly, through the nasal cavity into the trachea during the first stage in the procedure. Then, under fluoroscopic control, the radiologist directs the tube into the specific area he wishes to examine. A syringe filled with contrast medium is then connected to the tube and the medium is introduced under fluoroscopic control. One advantage of this method is that it offers selective visualization of a particular portion of the bronchial tree.

Supraglottic Method. The supraglottic method also called the "drip" method is the oldest and sometimes considered to be the least effective. The contrast medium is dripped, from a syringe fitted with a cannula, onto the back of the tongue where it flows into the trachea and lung fields. One disadvantage is that some of the contrast medium is swallowed and appears in the esophagus, possibly causing confusing shadows on the radiographs.

Intraglottic Method. The intraglottic method is similar to the supraglottic method. Instead of dripping the contrast medium onto the back of the tongue, the radiologist introduces it directly into the glottic using a syringe fitted with a long, curved laryngeal cannula.

Cricothyroid Method. In the cricothyroid method a needle is inserted directly into the trachea between the cricoid and thyroid cartilages. The contrast medium can be introduced through the needle or into a catheter that has replaced the needle. In case of the catheter, selective visualization of a portion of the bronchial tree is also possible. One major advantage with this method is that since the upper larynx is bypassed, the patient may not be as likely to cough, which can interfere with the examination. This method also seems to be the most popular with patients.

Exercises (644):

Match the bronchographic method of contrast media introduction in column B with the appropriate statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, more than one column B item may match a single column A entry.

Column A

___1. Requires the insertion of a needle.
___2. Used most often.
___3. Requires a catheter.
___4. Permits selective visualization of a specific part.
___5. May be least effective.
___6. Uses a long, curved laryngeal cannula.
___7. May provide confusing shadows of a contrast-filled esophagus.
___8. Reduces the patient's urge to cough.
___9. Most popular with patients.

Column B

a. Intratracheal intubation.
b. Supraglottic.
c. Intraglottic.
d. Cricothyroid.

3-3. Performing the Bronchogram

As far as you are concerned, the bronchogram is a fairly simple examination which involved nothing more than providing assistance, as needed, to the radiologist during various phases of the examination and then performing the post-fluoro radiographs. Some of your minor tasks, however, are important both to the success of the examination and to the welfare of the patient. We begin this section concerning the performance of the bronchogram with a look at one of the major problems, coughing.

645. Relate coughing by the patient to the success of a bronchogram and show how coughing affects your role during a bronchogram.

Coughing. When the contrast material is introduced into the patient's bronchial tree, he has a strong urge to cough—the more contrast material, the stronger the urge. This is a natural reflex action caused by irritation of the air passages by the material. If the patient coughs excessively during the examination, the examination may not be successful for two reasons. First, he may cough up the contrast material. Second, coughing may create a condition known as peripheral flood, in which the contrast material fills the minute air passages in the periphery, resulting in some difficulty in interpretation.

What can you do to help prevent the patient from coughing? In the first place, you should carefully explain the entire examination to him. Tell him exactly what is going to happen and when it will occur. Stress to him that he must try to refrain from coughing. If he feels the urge to cough, he should institute rapid, shallow breathing or "pant," which sometimes suppresses the urge to cough.

As mentioned before, the more contrast material in the patient's lungs, the stronger is the urge to cough. This means that when the examination nears completion and the entire amount of contrast material has been introduced, the patient's urge to cough is strongest. This is the time during which you will be performing the post-fluoro radiographs. Consequently, you must act quickly. It is best if two technicians perform the radiographs to further minimize the time.

Exercises (645):

1. What is the overall effect that excessive coughing by a patient during bronchography could have on the examination?

2. Give two reasons for your answer to exercise number 1 above.

3. How can you, by instructing or informing the patient, possibly help prevent him from coughing excessively?

4. What action should you take while performing the post-fluoro radiographs to help insure that the examination is not unsuccessful due to coughing?

646. Indicate the procedures for performing post-fluoro bronchographic radiographs.

Projections and Exposure. When the radiologist finishes the fluoroscopic phase of the examination, you perform the post-fluoro radiographs. Depending upon local policy, the radiographs are made with the patient recumbent on the X-ray table or erect in front of an upright cassette holder.

Both sides of the chest can be examined simultaneously, but more often only one side is examined on a given day. The projections you perform depend upon the side examined. Usually, a minimum of three radiographs are made—PA or AP, oblique, and lateral; however, this depends upon local policy. Anterior or posterior oblique projections can be made. If the right lung is examined and your radiologist wants posterior obliques, take a RPO. Take the opposite posterior oblique if the left side is examined. If your radiologist wants anterior obliques and the left side is examined, take an RAO—take the opposite anterior oblique if the right side is examined. All of these obliques demonstrate the lung field in question free of superimposition by the spine.

If only one side is examined, the correct lateral, of course, is the one that places the part under examination closer to the film. If both sides are being examined, a lateral projection after both sides are filled is not normally accomplished because superimposition of the two sides obscures structural details. However, a lateral of the first side filled with contrast material is usually accomplished before the opposite side is filled.

The exposure for the projections described should be increased slightly over that normally used for the lungs. The reason for the increase is to demonstrate those portions of the lung fields superimposed by the heart, and to demonstrate the trachea and primary bronchi which are superimposed over the spine. The exposure should be raised by approximately 5 to 10 percent of the kvp.

Exercises (646):

Answer the following exercises pertaining to the projections made after fluoroscopy during a bronchogram.

1. What minimum number of projections are usually made? What are they?

2. If only the right lung is being examined, what oblique projection should you make?

3. If only the left lung is being examined, what oblique projection should you make?

4. Why is a particular oblique necessary?

5. If both lungs are being examined (right lung first), how many laterals will you probably make and why?

6. If your answer to the first part of exercise number 5 above was *one*, which lateral would you make? If your answer was *two*, which lateral would you make first?

7. Why is it necessary to increase the exposure over that normally required for lung radiographs?

647. Briefly discuss the care of the bronchographic patient after the examination is finished, in terms of his coughing up the contrast material and ingestion of food or water.

Aftercare of the Patient. Once the examination is terminated, provide the patient with an emesis basin and instruct him to cough *gently* to remove the contrast material from his lungs, keeping him under observation until he leaves the radiology department. Be sure to stress that he is to cough gently because to cough harshly forces the contrast medium into the alveoli, in which case it can only be eliminated by absorption.

Also, of major importance is the fact that the patient's throat remains anesthetized for a number of hours following the examination. Because of this condition, he must not have *anything* to eat or drink until the anesthesia has worn off because, instead of the material being swallowed, it can be aspirated into the lungs.

Exercises (647):

1. Explain how the patient should be instructed to cough up the contrast material after the bronchogram and why.

2. How long after the examination should the bronchographic patient be refused water or food and why?

Contrast Studies of the Cardiovascular System

BLOOD IS circulated throughout the body by the circulatory or cardiovascular system. Occlusion, perforation, or disease of the blood-carrying vessels or of the heart produce serious and often permanent damage. Not only are the components of the cardiovascular system affected, but so are the organs and structures dependent upon them for blood supply. Prompt medical or surgical intervention is often required to correct anomalous conditions. Rarely, however, is such treatment initiated until accurate, comprehensive diagnostic tests have been completed. These tests include complete radiologic examination of the heart or of the affected vasculature. The procedures involved in this type of examination constitute angiography and are the subject of our discussion. Our study is conducted in two parts. The first portion concerns the physical structure of the cardiovascular system. The second part deals with various angiographic considerations including the contrast media, techniques of introducing the contrast media, forming catheters, and a brief look at some of the special equipment.

4-1. Anatomic Considerations

The cardiovascular system is comprised of blood, the heart, the arteries, the capillaries, and the veins. We begin our discussion with the blood and heart.

648. Name and give the locations of major structures associated with the heart.

The Blood. Blood is a thick, somewhat sticky fluid, the viscosity of which is nearly five times that of water. Basically red in color, it is almost scarlet in the arteries and crimson in the veins. On microscopic examination, blood is found to consist of numerous differentitated cells and fluid plasma.

The Heart. The heart is a hollow, muscular structure. As shown in figure 4-1, it is roughly cone-shaped and is situated above the diaphragm and between the lungs. The broad base is uppermost and centered to the midline. The narrow apex, or lower end, is located well to the left of the midline. The heart consists of a musculomembranous framework, blood-containing cavities or chambers, and specialized valves and orifices. We consider these components in the order given.

The fibromuscular structures. The cardiac wall or framework consists of three layers of tissue. These include the epicardium, the myocardium, and the endocardium (See fig. 4-1.)

The *epicardium* comprises the outer layer of cardiac tissue. It is a double-layered, sac-like structure which completely covers the myocardium, or heart muscle. The outer layer of the epicardium is called the pericardium.

The *myocardium* is a large, hollow, muscular structure which forms the bulk of the heart and gives rise to the interventricular and atrioventricular septa or partitions. The interventricular septum extends from the apex upward to the base, thus forming the right and left sides of the heart. The atrioventricular septa divide the heart horizontally. They are much smaller and thinner than the interventricular septum, and house two of the heart valves.

The *endocardium*, or lining of the heart, is the innermost layer of cardiac tissue. It completely covers the internal surfaces of the myocardium and gives rise to the heart valves.

The chambers, valves, and orifices. The four large cavities formed by the interventricular septum and the atrioventricular septa are referred to as the "chambers of the heart." These include the atria, which form the upper chambers, and

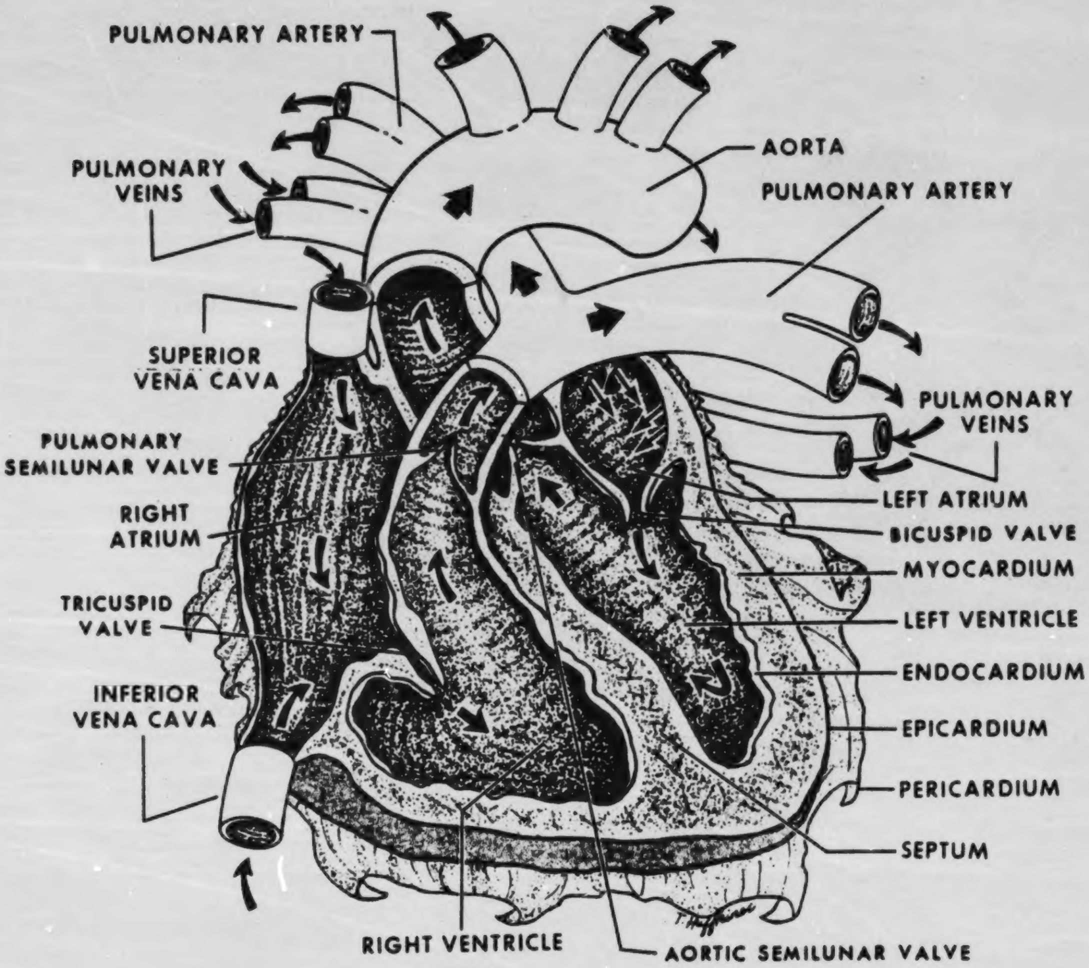

Figure 4-1. The heart.

the ventricles, which comprise the lower ones. These chambers, as well as the cardiac valves and orifices, are illustrated in figure 4-1. Refer to this illustration to familiarize yourself with these cardiac components.

The *right atrium* receives blood from all parts of the body except the lungs via the superior and inferior vena cava. The *tricuspid* valve is located between the right atrium and the right ventricle.

The *right ventricle* forms the right inferolateral aspect of the heart. It is a large cavity and gives rise to the pulmonary artery, which exits through an orifice in its superior aspect. This exit is guarded by the pulmonary semilunar valve, which consists of three cusps arising from the epithelial lining of the pulmonary artery.

The *left atrium*, smallest of the chambers of the heart, forms the left supralateral aspect of the cardiac organ. It receives the four pulmonary veins from the lungs, via four orifices in its posterolateral surface, and empties into the left ventricle by means of the left atrioventricular, or *bicuspid* (mitral) valve. This valve is comprised of two cusps arising from the endocardium.

The *left ventricle* forms the left inferolateral aspect of the heart. It is as large as its counterpart on the right and gives rise to the aorta. This large artery exits through an orifice in the superior aspect of the left ventricle. The exit is guarded by the semilunar valve of the aorta (aortic valve), which is comprised of the same type tissue and exhibits the same type of structure as the pulmonary semilunar valve.

Exercises (648):

1. Describe the locations of the base and apex of the heart.

2. What are the names and relative locations of the three main layers of the heart wall?

3. What is the name of the outer layer of the epicardium?

4. What dividing partition separates the heart into right and left portions?

5. In what direction does the atrioventricular septa divide the heart?

6. From what heart chamber does the pulmonary artery rise?

7. Where is the tricuspid valve located?

8. Where is the mitral valve located?

9. Which heart chamber receives blood from the lungs?

10. Which heart chamber(s) pumps blood through the aortic semilunar valve?

11. Which heart chamber receives blood from most of the body?

649. Name and locate key arteries about the chest, neck, and head.

The Arterial System. Blood is transported from the heart to the various organs, structures, and tissues of the body by an extensive network of arteries and arterioles. The large, centrally located aorta forms the trunk, and its ramifications, such as the subclavian, renal, and iliac arteries, form the branches.

The aorta. The first major vessel to be considered is the *aorta.* As you can see, in figure 4-2, this vessel arises from the superior aspect of the left ventricle. It first ascends obliquely and somewhat anteriorly to the right, forming a segment referred to as the "ascending" aorta. The vessel then curves posteriorly and to the left, to form the aortic arch. The aorta then descends behind the heart, along the left side of the anterior surface of the vertebral column, and to the diaphragm. This portion of the vessel is referred to as the "descending," or thoracic, aorta.

In figure 4-2, note that the aortic arch gives off three large branches. The first two branches off the aorta are the small right and left coronary arteries which supply the heart muscle with blood. The first of these is the innominate artery. As illustrated, this vessel, which is about 4 to 5 cm long, ascends obliquely to about the level of the right sternoclavicular articulation. At this point it splits to form the right subclavian and the right common carotid arteries.

Arteries of the head and neck. The arteries that carry blood to the cervical and cranial regions arise from the aortic arch, the innominate and the subclavians. As seen in figure 4-2, the ascending vessels include the left and right common carotids and they vertebral arteries. The left common carotid arises from the highest point of the aortic arch and ascends through the superior portion of the mediastinum into the neck. Its counterpart on the right passes directly into the neck from its point of origin at the bifurcation of the innominate artery. Once into the cervical region, the appearance and configuration of the carotid arteries and their ramifications are essentially identical. Therefore, we consider only those vessels supplying one side of the neck, face, and head. The same is true of the vertebral arteries.

The cervical portion of the carotid artery ascends obliquely through the neck to a point just about level with the superior aspect of the thyroid cartilage. Here it separates, forming internal and external branches.

The external carotid artery curves laterally and then ascends along the side of the neck. It gives off numerous branches which supply the upper neck, the face, and the scalp.

The internal carotid artery ascends almost vertically from the junction to the floor of the skull. It then follows a tortuous path through the petrous portion of the temporal bone. The vessel then passes medially along the surface of the sphenoid bone and gives off the ophthalmic artery, which supplies the eye and the orbit. The internal carotid then curves upwards and perforates the dura mater in the region of the sella turcica. It then bends upon itself and gives off the anterior cerebral, middle cerebral, posterior communicating, and choroidal arteries. These vessels supply the deep, midportion of the cerebral hemisphere. Figure 4-3 illustrates the internal carotid system and shows the vessels as seen from the right side.

The vertebral artery arises from the subclavian and, as illustrated in figure 4-3, ascends through the foramina of the transverse processes of the cervical spine to the base of the skull. It then passes through the foramen magnum and joins with its counterpart on the opposite side to form the basilar artery. Before they join, however, each vertebral artery gives off one inferior

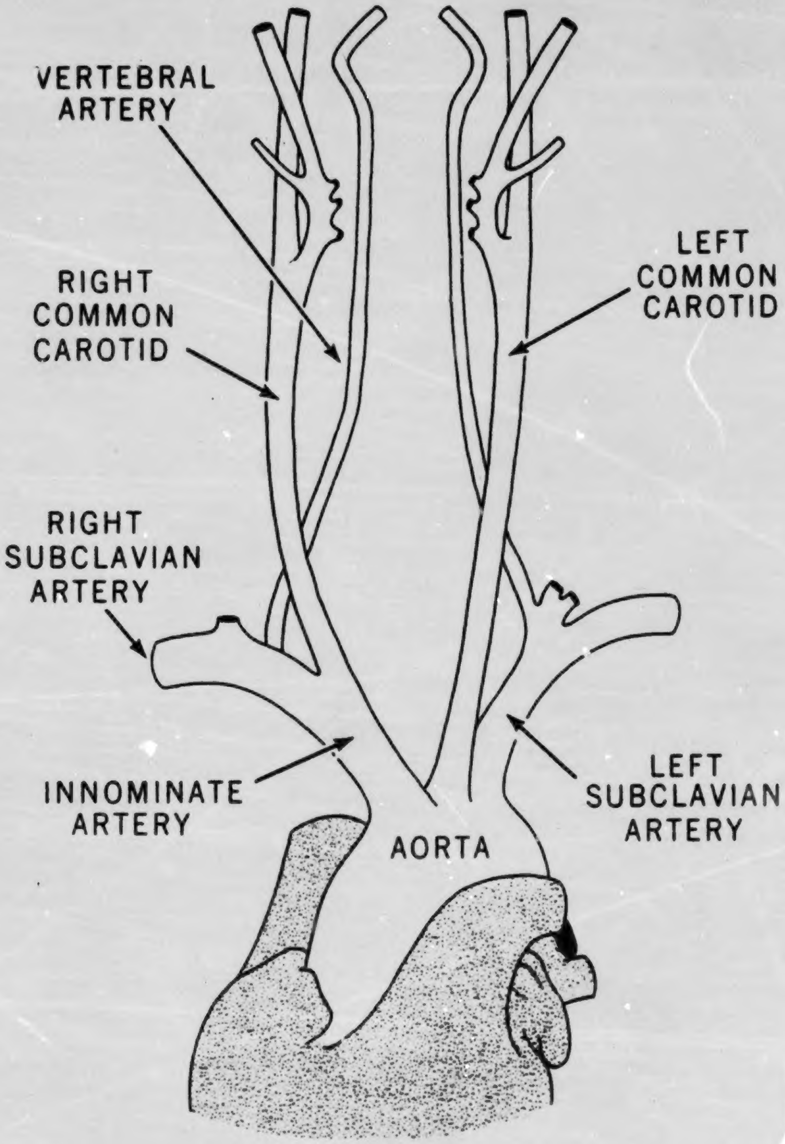

Figure 4-2. The aorta and its major branches.

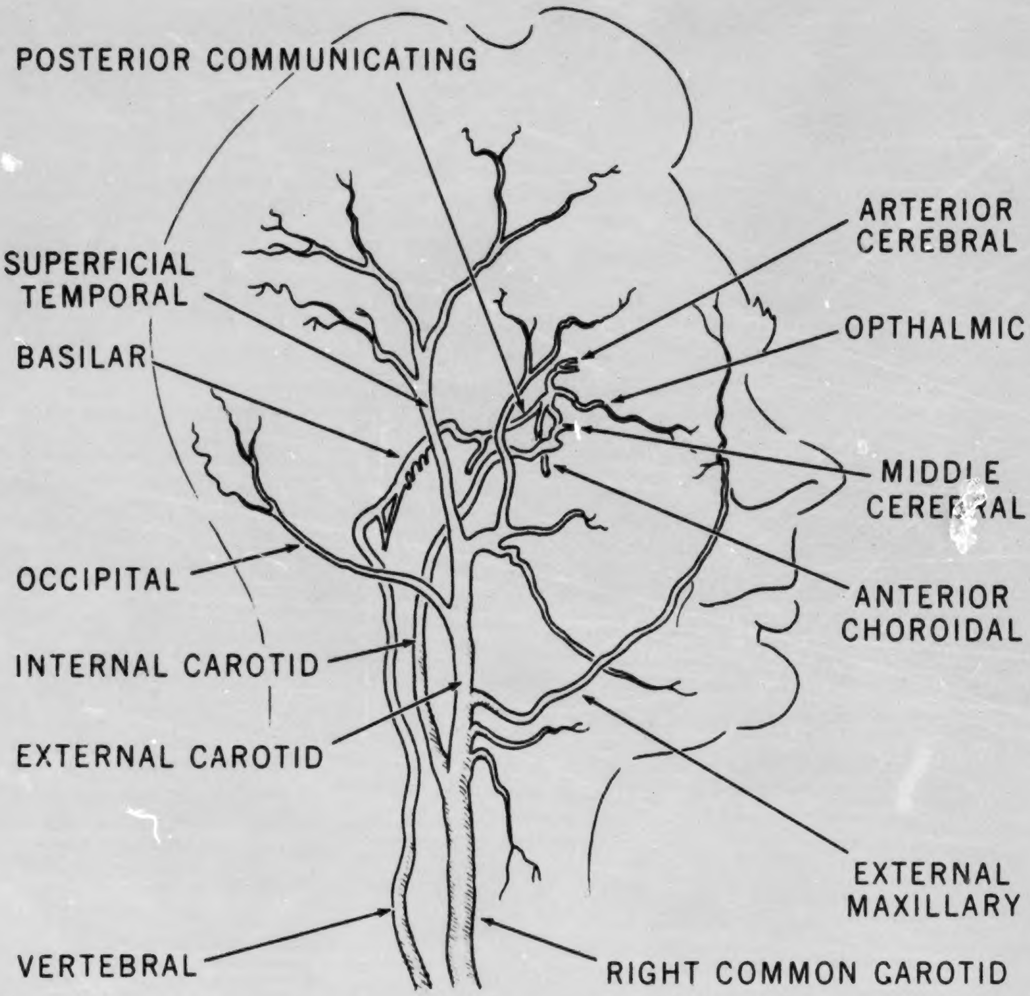

Figure 4-3. The arterial system of the neck and head.

cerebellar artery. These vessels pass through the foramen magnum and serve to nourish the lower portion of the hind brain. The basilar artery, usually a midline structure, ascends on an anteriorly angled course to a point about 1 cm posterior to the dorsum sellae. Here it gives off several branches which supply the cerebellum and the posterior aspects of the cerebral hemispheres. The basilar artery terminates in the posterior cerebral arteries.

The carotid and vertebral systems are joined, at the base of the brain, by the circle of Willis. Figure 4-4 illustrates the appearance and structural arrangement of this juncture. Notice that the majority of the circle is formed by branches from the carotid system. The anterior cerebral arteries are joined by the anterior communicating arteries to form the anterior portion of the circle, while the internal carotid and the middle cerebral arteries form the majority of its lateral aspects. The posterior portion of the circle is formed by the posterior communicating and posterior cerebral arteries and is the terminal end of the basilar artery.

Exercises (649):

Fill in the blank spaces below with one or two appropriate words.

1. The ____________ arises from the upper portion of the left ventricle.
2. To the point where the aorta curves posteriorly, it is known as the ____________ aorta.
3. The posterior curvature of the aorta is called the aortic ________________.

4. The descending aorta extends inferiorly to the ______________ .
5. The first two branches from the aorta are the ___________ arteries.
6. The first large branch off the aorta is the ____________ artery.
7. The _________ common carotid artery arises directly from the aorta.
8. Of the three large arteries exiting from the aortic arch, the ________________ exits nearest the descending aorta.
9. The right vertebral artery arises from the ___________ artery.
10. The common carotid branches into the ___________ and ______________ .
11. The ophthalmic artery is a branch off the _________________ .
12. The vertebral artery ascends through the ______________ of the cervical spine.
13. The lower portion of the hind brain is supplied by the ______________ arteries.
14. The ___________ artery terminates in the posterior cerebral arteries.
15. The ____________ of ____________ joins the carotid and vertebral arterial systems.
16. The anterior portion of the circle of Willis is formed by the _______________ and ______________ arteries.
17. The posterior portion of the circle of Willis is formed by the ______________ and ______________ arteries.

650. Name and locate key veins about the chest, neck, and head.

The Venous System. Blood is returned to the heart from the various organs, structures, and tissues of the body by a complex network of venules and veins. These vessels are structurally similar to the arteries and arterioles just described. Furthermore, the venous system forms a pattern almost identical to that of the arterial system. However, venous blood flows in a direction opposite to that of the arterial blood.

Veins of the head and neck. The vessels which comprise the venous network of the head and neck are divided into deep and superficial groups. The deep vessels of the head, those which drain blood from the brain, are comprised of the internal and external

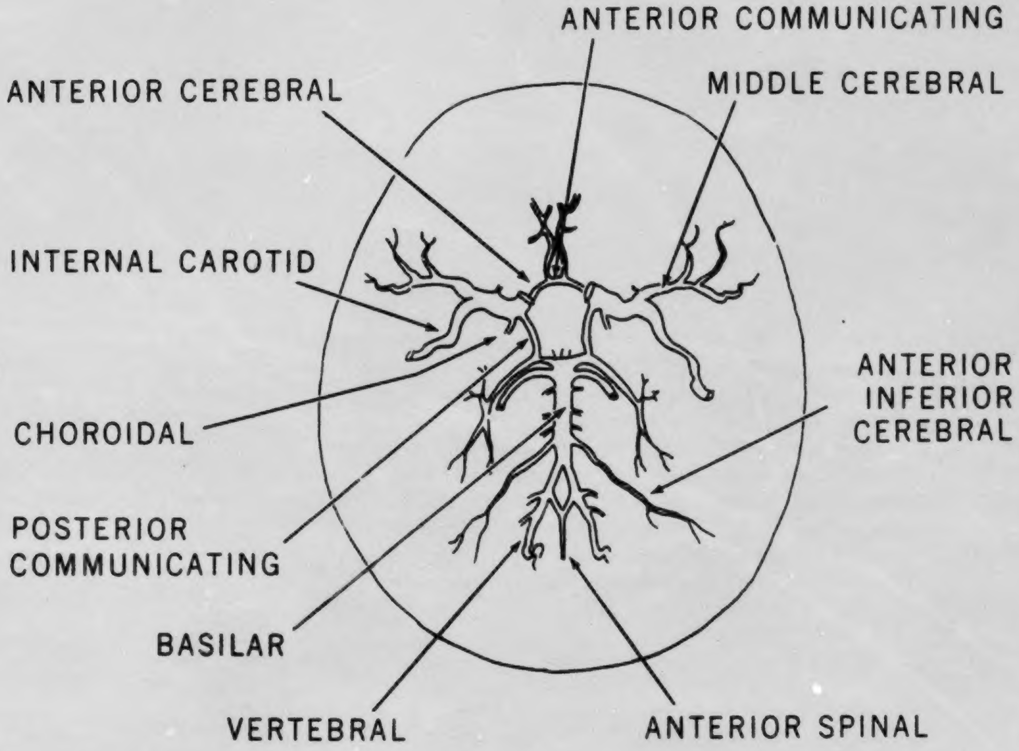

Figure 4-4. The circle of Willis and its ramifications.

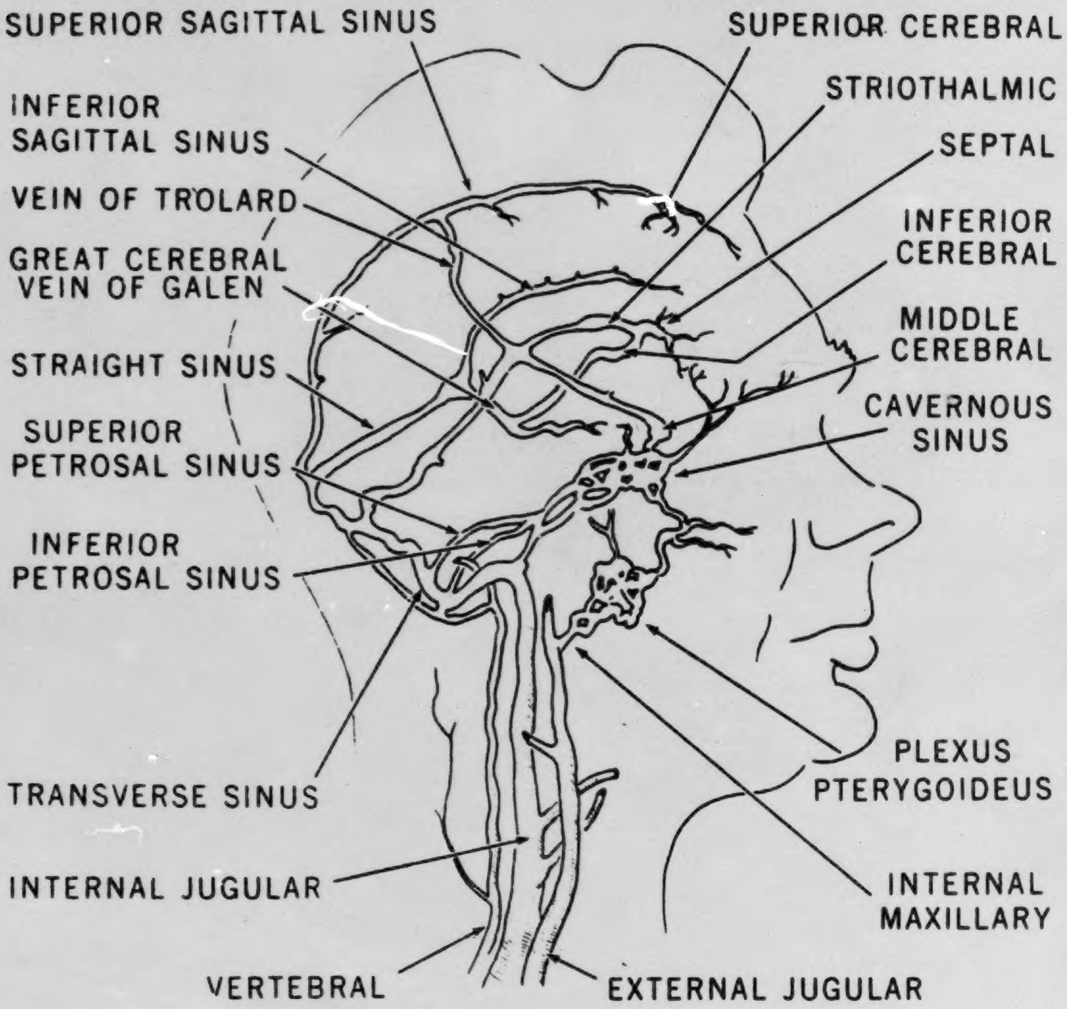

Figure 4-5. The venous system of the neck and head.

cerebral veins, the superior and inferior cerebellar veins, and the dural sinuses. Refer to figure 4-5 as we discuss these vessels.

The internal cerebral vessels, which empty the deep, midportion of the cerebral hemispheres, are the striothalmic (terminal) vein, the internal cerebral vein, and the great cerebral vein of Galen. The external cerebral vessels include the superior, middle, and inferior cerebral veins and the anastomotic veins of Trolard and Labbe. These veins empty the upper, mid, and basilar surfaces of the hemispheres. The cerebellar veins drain blood from the hind brain. All of these vessels empty into the dural sinuses. As you can see, these large vessels completely surround the brain. The superior and inferior sagittal sinuses lie along the margins of the falx cerebri (a fibrous, curtainlike structure which separates the superior aspects of the cerebral hemispheres). They are joined by the straight sinuses, into which the great vein of Galen empties. These sinuses join in the region of the internal occipital protuberance and form the confluens of the sinuses. The right and left transverse sinuses extend inferolaterally from this junction. They pass along the inner surface of the occiput and give rise to the inferior and superior petrosal and basilar sinuses. The latter gives rise to the sigmoid sinuses which empty into the internal jugular veins. There are no valves in these thin-walled venous structures or sinuses.

The superficial veins of the head, illustrated in figure 4-6, arise from the scalp and face. They describe a pattern similar to that of the external carotid arterial system and, for the most part, empty into the external jugular veins. As you can see, the occipital vein does not empty into either of the jugular vessels, but passes down the posterior aspect of the neck to join with the deep cervical and vertebral vessels. The anterior facial vein empties into both of the large neck veins.

The venous vessels of the neck consist of the internal jugular veins (which are the largest), the external jugulars (and their ramifications), the vertebral veins, and the deep cervical vessels. As illustrated in figure 4-5, the vertebral vein originates at the base of the skull and passes downward through the foramina in the transverse processes of the cervical spine. Thus, it follows a course closely approximating that of the vertebral artery. This vein empties into the subclavian vein.

The deep cervical vein arises from the suboccipital region and passes downward and forward to join with the vertebral vein in its distal reaches. The deep cervical receives the occipital vein and tributaries from the venous plexuses surrounding the cervical vertebrae.

The external jugular veins, as shown in figure 4-6, commence near the angles of the mandible. They descend along the lateral aspects of the neck to about the level of the clavicles where they empty into the subclavian veins. The external jugulars receive tributaries from the smaller anterior and posterior external jugular veins, from the superior veins of the base of the neck and scapula, and also from a large communicating branch from the internal jugulars.

The internal jugular veins arise from the sigmoid sinuses, pass through the jugular foramina in the floor of the skull, and descend, almost vertically, to join with the subclavian veins. These large vessels receive

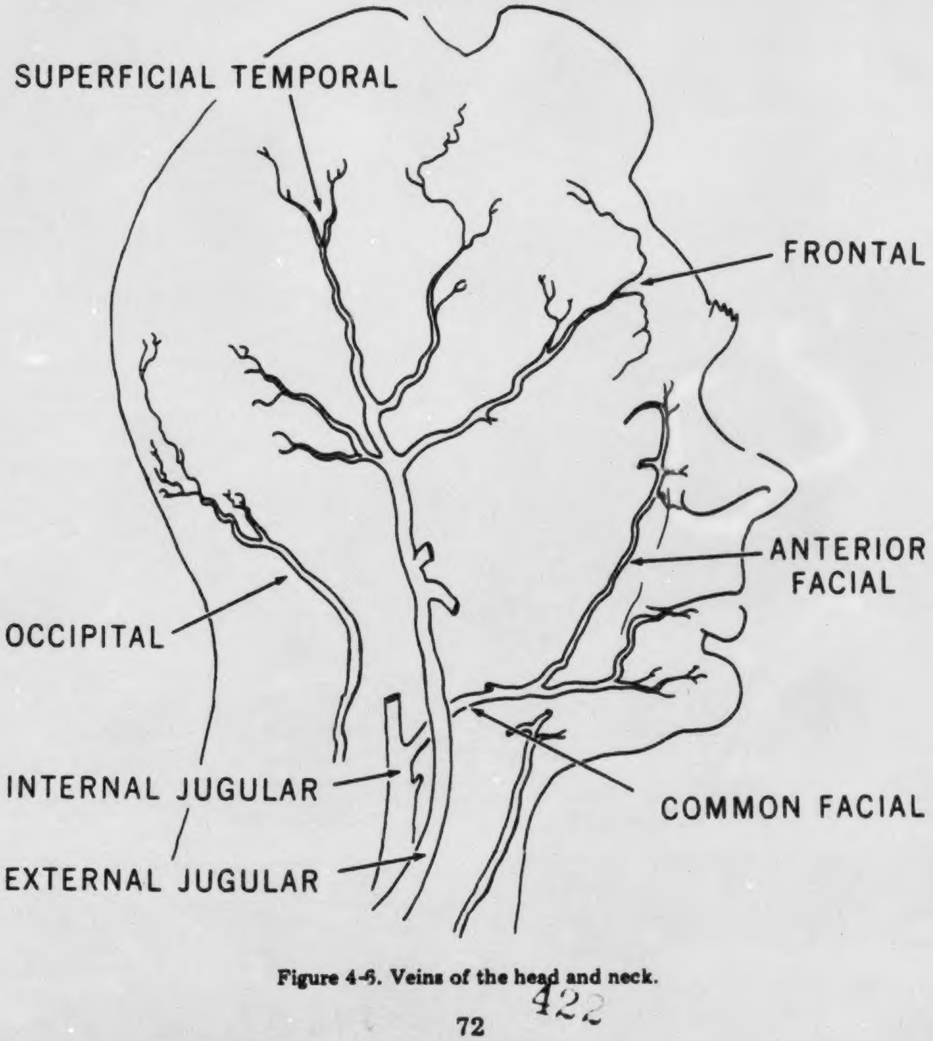

Figure 4-6. Veins of the head and neck.

branches from the common facial, lingual, pharyngeal, and the superior and middle thyroid veins. Although their primary function is to drain blood from the brain, they also receive and carry off blood from the face and the structures of the neck.

The subclavian vein extends medially, from the first rib to the sternal end of the clavicle. It lies anterior and inferior to the subclavian artery and receives several tributaries, including the external jugular vein. The subclavian joins with the internal jugular to form the innominate vein.

Veins of the thorax. The venous system of the thorax and mediastinum is comprised of the inferior vena cava, the tributaries of these vessels, and the pulmonary veins. The innominate veins are formed by the union of the internal jugular and subclavian veins. These junctures take place behind the sternal ends of the clavicles. The short, right vein descends along a sharply angled course to about the level of the cartilagenous portion of the first rib and the lateral aspect of the manubrium. Here it is joined by the more obliquely situated and longer, left innominate. The bilateral innominate veins unite to form the superior vena cava.

Exercises (650):

1. Name three veins that empty the deep midportion of the cerebral hemispheres.
2. What portions of the cerebral hemispheres are emptied by the cerebral and anastomotic veins of Trolard and Labbe?
3. What large vessels completely surround the brain?
4. Where are the superior and inferior sagittal sinuses located?
5. Into what vein does the sigmoid sinus empty?
6. Are the transverse and basilar sinuses considered deep or superficial drainage channels?
7. Does the occipital vein empty into the external jugular vein?
8. Where does the vertebral vein originate?
9. Where does the vertebral vein empty?
10. With what vein does the deep cervical vein join distally?
11. Where does the external jugular vein originate?
12. Into what vein does the external jugular empty?
13. The subclavian and internal jugular veins unite to form what vein?
14. What vein results from the union of th innominate veins?

4-2. Angiographic Considerations

Radiography of the vascular system, or angiography, while basically aimed toward the same results, is performed in many different ways. A simple angiogram consists of a "needle and syringe" injection into an extremital vessel after which a single radiograph is made showing the vessel under examination. Or, an angiogram can be performed after a catheter is passed into a coronary artery using a sophisticated apparatus that triggers the injection and filming procedures at a specific phase of the heart beat. In addition, there is wide variance in the manner in which a specific angiogram is performed from one hospital to another.

Due to the dissimilarity of specific procedures and techniques, we only present you with information that is basic and general in nature. Keep in mind that many technical aspects of radiography, such as those related to exposure, FFD, tube ratings, etc, have been presented in volume one of this CDC and apply to angiography as well as other radiographic examinations.

We begin this section with a discussion of angiographic contrast media. After that we discuss aspects, such as introductory techniques, forming catheters, film changers and automatic injectors.

651. Indicate the uses and adverse effects of angiographic contrast media and briefly discuss the importance of good diagnostic angiograms in relation to the contrast media dosage.

Contrast Media. Angiographic contrast media are similar and often identical to those used for intravenous urography—that is, they are injectable organic iodides. (Injectable in this case means that they can be injected into the vascular system.)

Concentration and dosage. The concentration of the contrast medium, or we might say the opacity, is determined by the amount of iodine it contains—because iodine is the substance that absorbs the X-ray photons and outlines the vessels under study. Highly concentrated media are used to prevent excessive dilution due to the high volume of blood found in the heart and large vessels. Moderately concentrated media are used where blood volume does not significantly dilute the medium. Dilution of the contrast medium can also be prevented by injecting a relatively high dose.

Adverse effects. Contrast media administered during angiography can cause reactions similar to those discussed in chapter 2 of this volume. Also, due to the higher concentration of some angiographic media and the rapid rate in which it is injected, the greater is the chance of a serious reaction.

Another increased hazard associated with the injection of angiographic contrast media is that certain sensitive areas are more susceptible to reaction when the contrast medium is introduced directly into them. For example, during a renal arteriogram, the medium is either introduced directly into the renal artery or it is introduced into the aorta just proximal to the renal artery. Consequently, this medium reaches the kidneys in a more concentrated form than if it were injected into the arm for an IVP. Thus, the danger of damage to the kidney tissue is greater. The heart and the brain are other areas where direct introduction of the medium poses potential dangers.

Due to the dangers from direct introduction of the contrast medium, there is a limit to the amount of contrast medium that can be introduced into the sensitive areas during one examination. Why is this important to you? Well, consider a renal arteriogram where the first injections of the contrast material were in vain because the radiographs were technically inadequate. Your radiologist may have to delay the next injection to allow possible hemodynamic disturbances to subside. In fact, it is possible that he may have to cancel the examination altogether for that day if more than one injection is carried out without adequate radiographs. Keep in mind that some angiograms are traumatic procedures for the patient, so you must take all the necessary precautions to see that good, diagnostic radiographs are produced the first time—lest the entire procedure be repeated. Naturally, a delay in the diagnosis of the patient's condition may also result.

Exercises (651):

1. How is excessive dilution of the contrast medium overcome for angiographic studies?

2. Give three reasons why angiographic contrast media increases the chance of a serious reaction.

3. Briefly discuss the importance of performing good diagnostic angiograms the first time.

652. Compare the three methods for introducing the contrast medium during an angiogram.

Introductory Techniques and Devices. Refined methods and, in certain instances, sophisticated injection devices are used to introduce contrast material into the vasculature. The techniques include *percutaneous injection*, *selective catheterization*, and a combination of these called *percutaneous-selective catheterization*, or Seldinger's technique.

Percutaneous injection. Percutaneous simply means "through the skin." This technique is performed by passing a spinal, abdominal, or hypodermic needle through the skin, the subcutaneous and muscle tissue, and into the vessel to be demonstrated. The two-part spinal needle is more often used. One part consists of a hub and cannula, and the other is a trocar. The slender trocar has a very sharp point, while the cannula is usually blunted. The trocar is passed through the cannula and does the cutting. Once into the vessel, it is removed and the dull cannula is left in place. Thus, the arterial or venous walls are not subjected to any more damage than is absolutely necessary. A syringe filled with physiological saline is then attached to the hub of the needle, either directly or by means of tubing and an adapter. This salt water solution is injected by hand in the standard manner. It serves to clear the cannula and the area around its tip of debris resulting from passage through the vessel wall. Following the injection of saline, another syringe filled with moderately concentrated contrast material is attached to the needle in the same manner. Again, injection is made by hand in the standard manner. Percutaneous injection is usually restricted to procedures that require only small amounts of contrast material. Thus, it is generally employed for carotid, femoral, and peripheral angiography, and vena cavography.

Selective catheterization. Selective catheterization involves the passage of a long, thin-walled catheter through an artery or vein into the heart or aorta. A surgical cutdown is performed to expose the vessel through which the catheter is to be threaded. As a rule, the femoral artery (below the inguinal ring), the antecubital vein, or the brachial artery are the vessels exposed. The vessel is incised and the catheter inserted and threaded to the desired position under fluoroscopic control. When it is in place, the catheter is sutured to the vessel and the surrounding tissue. The incision is then closed and dressed. A contrast-medium-filled syringe is attached to the exposed end of the catheter by an adapter, and injection can be made by hand. However, the procedures for which this technique is employed usually require large amounts of highly concentrated material. Consequently, automatic pressure injectors are more often used to force the medium through the catheter and into the structures to be visualized. Selective catheterization can be used for angiocardiography, thoracic aortography, coronary arteriography, thoracic aortography, coronary arteriography, lumbar aortography, and selected abdominal arteriography.

Percutaneous-selective catheterization. Percutaneous-selective catheterization (Seldinger's technique) is a combination of the techniques just described. This technique involves percutaneous insertion of a special needle into the lumen of a particular vessel (usually the femoral artery, just below the inguinal ring) followed by selective catheterization. The needle, rather than a surgically exposed vessel, serves as the introduction site for the catheter. The needle consists of either two or three parts. It is inserted into the vessel, and physiological saline is injected in the same manner and for the same reasons as described for the standard percutaneous injection. A special, very flexible guide wire is then passed through the needle and into the lumen of the vessel. The wire is threaded, under fluoroscopic control, through the vasculature to the desired position. When it is in place, the needle is removed and a long, thin-walled catheter is passed over the guide wire, through the puncture site, and into the lumen of the vessel. From there it is threaded under fluoroscopic control through the vasculature to the desired position. The guide wire is then removed and the position of the catheter is fluoroscopically rechecked. Heparinized saline (a solution of heparin, an anticoagulant, and physiological saline) is usually injected by hand to preclude obstruction of the catheter tip because of the blood clotting. Injection of contrast material is made either by hand or by automatic pressure injector. Percutaneous-selective catheterization is widely used for abdominal arteriography and aortography.

Exercises (652):

Match the method for introducing angiographic contrast media in column B with the appropriate statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, more than one column B item may match a single column A item.

Column A	*Column B*
___ 1. Uses a catheter.	a. Percutaneous injection.
___ 2. Catheter is passed over a guide wire.	

Column A

_ 3. Injection is usually by hand.

_ 4. Automatic injection is more often used.

_ 5. The catheter may be sutured in position.

_ 6. Contrast medium is injected through a needle.

_ 7. A needle is introduced into a blood vessel.

_ 8. Injection can be by hand or by an automatic injection.

_ 9. Generally used for peripheral angiography.

10. Includes a surgical cutdown.

_11. Guide wire is removed from within the catheter.

Column B

b. Selective catheterization.

c. Percutaneous-selective catheterization.

653. Indicate why angiographic catheters must be formed and the reasons for forming them locally.

Forming Angiographic Catheters. Most angiograms are performed with the contrast material injected through a catheter which has been inserted into the vessel under study. A typical example is a renal arteriogram where a catheter is inserted percutaneously into the femoral artery and passed through to the renal artery. The ends of these catheters must be shaped to facilitate entry into the remote site of injection and so that the catheter will maintain its position. Five such ends are shown in figure 4-7. Several manufacturers market catheters that are preshaped for many angiographic studies. However, these catheters are quite expensive. Also, because of the many variations in the vessel anatomy because of the physical size and condition of the patient, there are times when a special catheter is needed that is not available through commercial channels.

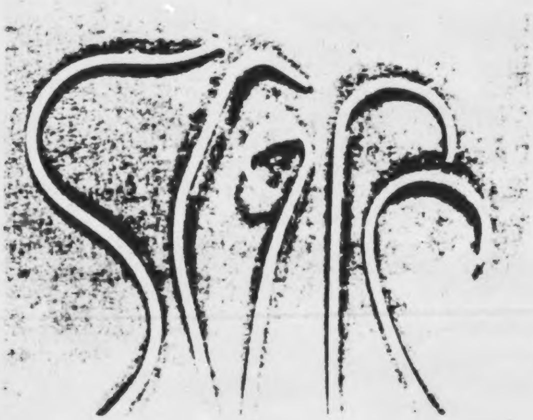

Figure 4-7. Five ends of angiographic catheters and various shapes.

For the above reasons, many radiology departments "make" their own angiographic catheters. Manufacturers also market rolls of catheter tubing, up to 20 feet long, so that you can form your own.

Exercises (653):

1. Why must the ends of angiographic catheters be specially formed?

2. Why should you form your catheters locally rather than purchasing them preformed?

654. Specify what procedures to follow when forming catheters and why.

General considerations. Catheter tubing is made from various materials, for example, "nylon," "Teflon," or "polyethylene." Each tubing manufacturer encloses specific step-by-step instructions on how to form the material in question. Since some catheter-forming procedures cannot be used on all materials, be sure to follow the manufacturer's recommendations accompanying the roll of catheter tubing. Also, as newer materials and techniques are discovered, these procedures have a tendency to become outdated quickly. Polyethylene catheters are used frequently by many radiologists for angiograms—therefore, we provide some general procedures and considerations to be applied when forming these catheters.

Exercise (654):

1. What procedures should you follow when forming catheters and why?

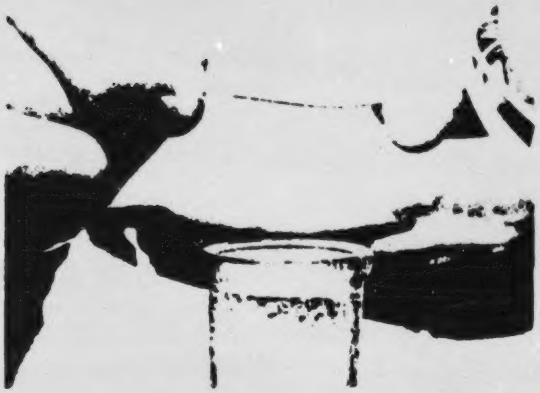

Figure 4-8. Position of the catheter over a beaker of boiling water before tapering.

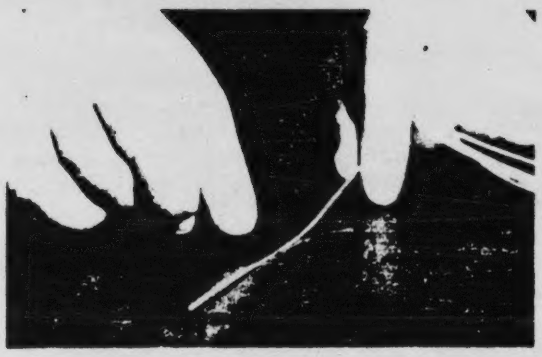

Figure 4-10. Cutting the short end of the tapered section with a scalpel blade.

655. Indicate why the end of an angiographic polyethylene catheter must be tapered, the procedures used for tapering, and the resulting specifications.

Tapering the tip of the catheter. If the catheter is to be inserted into a vessel over a guide wire, and most of them are, its tip must be tapered. The reason it must be tapered is to permit the catheter to be easily passed over the guide wire as it, the catheter, enters the wall of the vessel. Tapering the catheter reduces the thickness of its walls as well as its internal diameter. The internal diameter of the tapered tip must fit snugly over the guide wire but must not be so tight that it prevents passage of the catheter over the wire. (NOTE: Always wear surgical gloves when handling catheter tubing to prevent the natural oils from your skin from adhering to the catheter. Also, the gloves must be free of powder. Unpowdered commercial gloves are available but you can also rinse the powder off standard gloves. This procedure is to prevent the powder from adhering to the catheter.)

To taper the end of a polyethylene catheter, hold a small section near the end of the tubing above a small flame or above a beaker of boiling water, as shown in figure 4-8. Rotate the catheter until the exposed section softens from the heat of the flame or from the steam. Stretch the tubing by pulling against the softened section with your fingers until the diameter of the softened section is sufficiently reduced. See figure 4-9. Immediately immerse the softened section in cold water until it hardens. Cut the short end of the catheter off with a sharp razor or scalpel blade, as shown in figure 4-10. The length of the tapered section depends upon the examination to be performed and your radiologist's preference—usually it is less than 2 cm. To insure that the internal diameter of the tapered segment is correct, pass the tapered section over the guide wire—the same

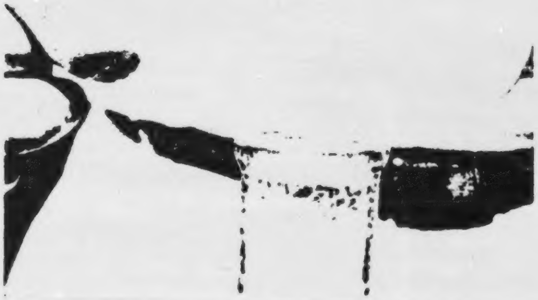

Figure 4-9. Showing the tapered section of tubing after it has been softened and stretched.

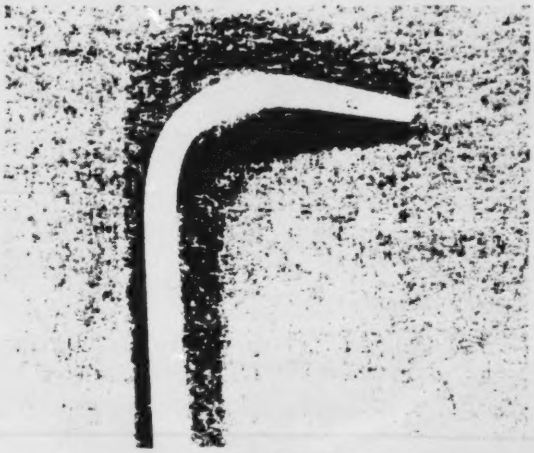

Figure 4-11. Close-up of a tapered catheter.

size as that used with the catheter. It should fit the guide wire, as previously described. Some techniques taper the end of the catheter with the guide wire in place, which is more likely to make the internal diameter of the catheter compatible with the diameter of the guide wire. If you do not use the guide wire, a common error in stretching the catheter is to make the internal diameter too small for passage over the guide wire. However, this problem is usually overcome with practice. After you are satisfied that the tapered end and guide wire are compatible, smooth the cut end of the tapered section with emory paper (specifically, that recommended by the manufacturer) by brushing toward the end. The tapered end should appear approximately like that shown in figure 4-11, except for its length, which varies.

Exercises (655):

1. Why should the end of an angiographic catheter be tapered?

2. Briefly discuss the type of gloves to wear when handling catheter tubing and why gloves are worn.

3. Briefly explain the procedure for stretching the catheter.

4. How should the stretched section of the catheter be hardened?

5. How long should the tapered section be after it is cut?

6. How should you test the compatibility of the internal diameter of the catheter and the guide wire?

7. What results should you achieve with the technique indicated in exercise number 6 above?

8. Until you are experienced in stretching the catheter tubing, how can you keep from stretching the catheter excessively, thereby making its internal diameter too small?

9. How should you smooth the tip of the tapered section?

656. Give necessary details pertaining to the procedure for forming the end section of a polyethylene catheter.

Forming the end section of the catheter. After you have tapered the end of the catheter, the next step is to form or shape the end of the catheter. You can either use a "forming wire" commercially supplied, preshaped or straight, or a guide wire. The straight forming wire and the guide wire allow you to shape the catheter to your radiologist's specifications. If you use a preshaped forming wire, simply insert it into the catheter. The end section of the catheter will, of course, take on the shape of the wire. Rotate the catheter over heat as before or immerse it in hot water, above 140° F, until it softens. Do not immerse the tapered end of the catheter into the water because its thin walls will become damaged. After the catheter softens, immediately immerse it in cold water until it hardens. After hardening, the catheter will then remain shaped as was the wire. If the catheter does not retain the shape of the wire, you probably did not allow it to soften sufficiently.

If you use a straight-forming wire or a guide wire to shape the tubing, simply insert the guide wire, shape the wire and tubing as desired and carry out the procedure described above. If you use the guide wire, use the end not inserted into the patient—because that end is more stiff than the other and retains its shape better. Figure 4-12 shows a preshaped forming wire along with a catheter shaped from that wire.

Exercises (656):

1. List three types of wires that are used to form the end section of the catheter.

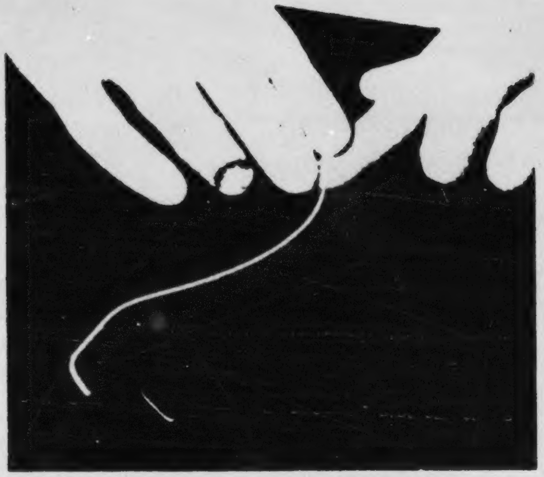

Figure 4-12. A preshaped forming wire and catheter formed from the wire.

2. If you soften the catheter by immersion in water, what minimum water temperature should be used?

3. Explain how to use a guide wire to form the catheter.

4. If you do not soften the catheter sufficiently, what condition is likely to occur?

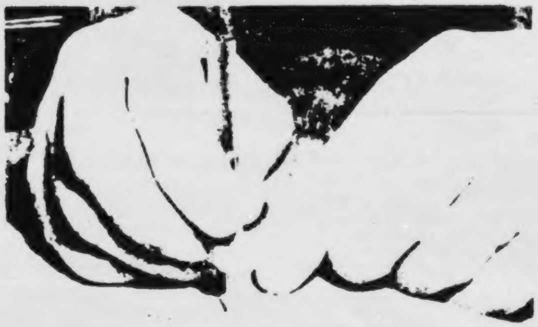

Figure 4-13. Cutting a side hole.

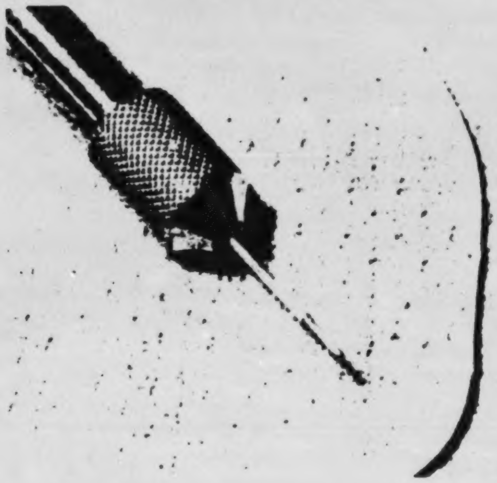

Figure 4-14. Cannula, stylet, catheter with side holes, and removed plugs.

657. Give two reasons side holes are required in a catheter and provide three precautionary measures to observe when cutting the holes.

Cutting side holes. Certain angiographic examinations require side parts or holes in the end of the catheter. These holes are necessary in some cases to supplement the end hole and increase the delivery rate of the catheter. Also, they sometimes reduce catheter "whip," a recoil effect which sometimes occurs when a large volume of contrast material is injected under high pressure.

If you must cut side holes in the end of the catheter, use a commercial "hole punch" available from the catheter manufacturer. It consists of a cannula and blunt stylet. Press the cutting edge of the cannula against the wall of the catheter, as shown in figure 4-13.

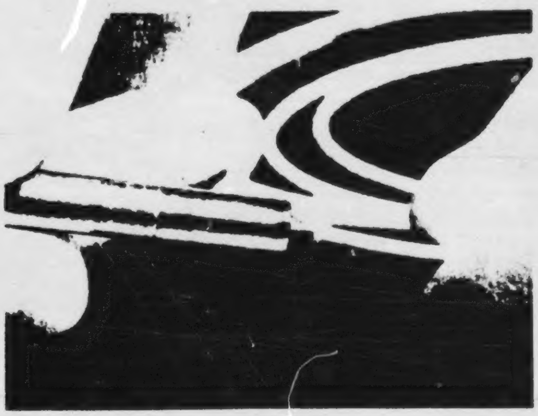

Figure 4-15. Flaring the catheter with a flaring tool.

Use gentle pressure and rotate the cannula until the hole is cut. Then insert the stylet into the cannula to remove the plug. Make sure you remove each plug from the catheter so that they will not be injected into the blood stream. (See fig. 4-14.)

Your radiologist will tell you how many holes to cut and approximately where to cut them. To prevent the guide wire from being passed through a side hole, do not cut the holes along a curved portion of the catheter. Also, do not cut side holes directly opposite one another or on the tapered tip of the catheter—otherwise, the catheter can become significantly weakened.

Exercises (657):

1. Why are side holes sometimes cut in the end of a catheter?

2. List three precautions you should observe when cutting side holes and in each case briefly explain why the precaution is necessary.

658. Briefly discuss the reason and procedure for flaring a catheter and a common place and cause of an obstruction.

Flaring the catheter. The final step in forming a catheter is to cut the tubing to the desired length and to flare or flange the end—the end remaining outside the patient. To flare the end, use a flaring tool supplied by the tubing manufacturer. Push the tip of the catheter onto a warmed flaring tool, as shown in figure 4-15. You can also soften the end of the catheter as opposed to warming the flaring tool. After the end is flared sufficiently, set the flare in cold water as before. The flared end is shown in figure 4-16.

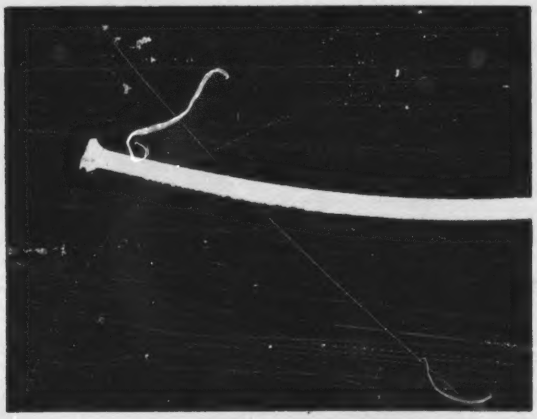

Figure 4-16. The flared end of a catheter.

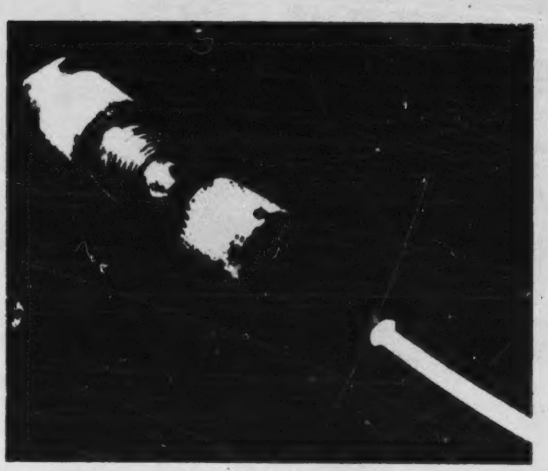

Figure 4-17. Two-piece connector and the flared end of a catheter.

The tip is flared to accommodate a two-piece connector shown in figure 4-17. The connector, of course, permits the connection of a syringe or syringe tubing containing the contrast medium. Some radiologists prefer to sterilize the catheter with the connector assembled. Others assemble the connector to the flared end immediately before use. If you assemble the connector, make sure you don't obstruct the end of the catheter in the process. A likely place for an obstruction is at the flared end caused by improperly fitting the connector.

Exercises (658):

1. Why is the end of a catheter flared?

2. Briefly discuss the procedure for flaring the end of a catheter.

3. Give a common site and cause for an obstructed catheter.

659. Describe the sterilization procedures to use for angiographic catheters.

Sterilizing angiographic catheters. Before sterilizing the catheters, be sure to read and follow the manufacturer's recommendations. Polyethylene, on which our entire discussion of catheter forming is based, cannot be autoclaved and chemical immersion sterilization is not recommended. This leaves gas sterilization as the only method. Also, do not use gas sterilized polyethylene for a few days after sterilization.

Some "Teflon" catheters can be safely sterilized using any approved procedure including autoclaving as long as the autoclave temperature does not exceed 250° F.

Exercises (659):

1. What instructions should be followed to sterilize angiographic catheters?

2. What is the only method to use when sterilizing polyethylene catheters?

3. Certain "Teflon" catheters can be autoclaved at what maximum temperature?

660. Compare major features of the three types of automatic film changers.

Automatic Film Changers. Most angiographic examinations require radiographs made with an automatic film changer. Conceivably cine or video tape systems could perform the same function of recording several "pictures" of contrast filled vessels per second but both of these systems do not reproduce the fine detail needed for these studies. We first examine the types of changes and then some of the uses and problems encountered.

Types of automatic changers. Several types of automatic film changers are on the commercial market and found in Air Force hospitals. Basically, they can be broken down into three categories: (1) the cassette changer, (2) the roll film changer, and (3) the cut film changer.

Historically, the cassette changer was the first automatic changer to receive extended use in angiography and it is still used for some angiograms with excellent results. One of the problems encountered with a cassette changer is that it is not as reliable mechanically as the other two types. There is a tendency for the unit to jam, especially after the cassettes are used repeatedly and become worn or damaged. Another problem is that it cannot achieve the rapid change rate that can be achieved by others. The relatively slow rate limits the use of this type of changer to angiograms that do not require several films per second.

Another significant problem encountered with a cassette changer not present with roll or cut film changers is that, due to the weight of the cassettes as they are transferred from one point to another, the unit has a tendency to vibrate. Obviously, this vibration can cause slight movement of the patient and result in motion on the radiographs. As a rule the motion is most striking on a projection, such as the AP skull where the part is relatively unstable. If vibration of your cassette changer results in part motion, you should use an extension band on the X-ray table to support the head instead of resting the head directly on the changer.

The roll film changer is somewhat of an improvement over the cassette changer in that more radiographs can be made per second. This improvement results from the fact that mechanical movement of film on a roll is easier to accomplish than that of cassettes. This type of changer is more reliable mechanically than other types. The fact that the film is rolled, however, does not lend itself to the economical use of film. Between examinations, a new leader must be inserted into the receiving magazine, which results in wasted film. Also, the end of a roll may also have to be discarded if it is not long enough to accommodate the next examination, resulting in a further waste of film. The roll film changer does not experience the vibration of a cassette changer.

The cut film changer solves some of the problems of both the other types of changers. Single sheets of film are advanced instead of cassettes or a roll. This type of changer can produce more films per second, prevent film waste, and of course reduce vibration caused by the movement of heavy cassettes.

Exercises (660):

Match the type of film changer in column B with the appropriate statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once, or more than once. In addition, more than one column B item may match a single column A item.

Column A	*Column B*
_ 1. Has a tendency to vibrate.	a. Cassette changer.
_ 2. Most reliable, mechanically.	b. Roll film changer.
_ 3. Has slowest filming rate.	c. Cut film changer.
_ 4. Wastes film.	
_ 5. Least reliable mechanically.	
_ 6. Has high filming rate with little film waste.	
_ 7. Little vibration.	

661. Indicate the advantages of a see-through film changer.

One recent improvement in automatic film changers is the "see-through" changer. This improvement allows the use of an image tube positioned so that the area can be fluoroscopically monitored simultaneously with the filming. Not only does this allow the radiologist to monitor the area with television but it allows the injection to be recorded on video tape. The advantage of the video tape recording is that the tape can be played back immediately enabling the radiologist to quickly determine whether or not the examination is successful. Otherwise, he must wait until the "changer" radiographs are processed.

Exercise (661):

1. What are the advantages of a see-through film changer?

662. Give two advantages and two problems pertaining to biplane film changer operation; indicate corrective measures necessary to overcome the problems.

Biplane changer operation. If two X-ray tubes are used to simultaneously make AP or PA and lateral radiographs, the examination is a biplane study. One obvious advantage of biplane studies is the reduction in the dosage of contrast medium—the patient receives one dose for a biplane study, but he receives two doses for separate studies. Another advantage, the most significant one, is that the radiologist can study the structures more accurately if right angle studies are made simultaneously.

One of the major problems you will encounter during a biplane examination is the presence of scatter radiation causing film fog. Since you have two X-ray beams exposing the patient, scatter radiation is approximately twice normal. One solution to this problem of excessive scatter is to use two crossed grids (described in volume 1). At times, however, you cannot use two crossed grids. For example, if one of the two projections, such as the AP cerebral angiogram, requires an angled C.R., you cannot use a crossed grid due to the absorption of primary radiation.

Even though you use two crossed grids, and collimate properly, film fog will be slightly more evident than during single plane operation. Consequently, the exposure you use for a biplane projection should be slightly less than that used for the same projection during a single plane study. The reduced exposure is necessary to maintain the same film density from one examination to the next. Consequently, you will have to use a linear grid for the AP. You can use a crossed grid for the lateral in this case because the C.R. is perpendicular to the grid. Precise collimation of both beams to the parts under study is absolutely necessary during biplane operation to reduce the scatter radiation.

Another problem sometimes encountered with a biplane cerebral angiogram is the loss of detail due to the large part-film distance on the lateral. Depending on the type of changer you have, you may not be able to achieve close contact between the side of the patient's head and the changer. This condition results in some detail loss—the amount depending upon the part-film distance present. To compensate for the increase in part-film distance, increase the FFD—perhaps to 72 inches if the part-film distance is considerable.

Exercises (662):

1. What are two advantages of biplane film changer operation?

2. List two problems encountered during biplane filming. In each case, indicate how the problems can be overcome.

663. Briefly discuss the primary considerations requiring your attention when using an automatic injector.

Automatic Injectors. Automatic injectors are highly sophisticated devices that introduce large amounts (up to 100 ccs) of contrast media into the blood system under great pressure (up to 1000 pounds per square inch). Several different models are used throughout Air Force hospitals, and, although they all serve the purpose, the operating principles and instructions vary.

As far as you are concerned, there are two major areas of concern pertaining to an injector. The first is that you must completely understand the operation of your particular injector. This means that you will have to study the manufacturer's operating instructions in detail until you understand all aspects of the operation.

The second concern was discussed in volume 1, but, because of its importance, we review the particulars here. When an injector is connected to a catheter, which is inserted into the blood stream, it only takes approximately 1/1000 of the lethal skin current to produce ventricular fibrillation in the patient. The reason for this is because the resistance of the skin is bypassed by the contrast medium in the catheter. The significance of this condition is that a very small amount of leakage current from an injector, even in good repair, can electrocute the patient. As explained in volume 1, you must insure that the injector, X-ray table, and other electrical appliances in the room are grounded to the *same* ground potential to reduce the possibility of the patient becoming electrocuted.

Exercises (663):

1. Briefly discuss your role in the operation of an automatic injector.

2. Briefly discuss the electrical hazard present when an automatic injector is used and give the necessary precaution.

CHAPTER 5

Contrast Studies of the Nervous System

ALL OF OUR specialized senses (sight, hearing, smell, taste, and touch) as well as our organic functions (respiration, circulation, digestion, etc.) are governed by a complex neural network which is referred to as the "nervous system." Actually, this network is comprised of two major components, the central and the peripheral nervous systems. The latter is further divided to include the autonomic nervous systems. Since, however, we are concerned only with the central system, this portion of our discussion is limited to central nervous system structures; for example, the brain, spinal cord, meninges, and the ventricular system. The brain is encased by the cranial bones, and the spinal cord is surrounded by the bony structures of the vertebral column. Further protection is afforded by three layers of membranous tissue—the meninges—which completely invest both the brain and the cord. The cerebrospinal fluid flows through this closed and continuous system to cushion the brain in its solid vault. In order to examine each section of the system in more detail, we consider them separately and in conjunction with the radiographic procedures used to visualize them. We begin with a study of the myelogram.

5-1. Myelography

As you know the special radiographic procedure employed to demonstrate abnormalities of the spinal cord is referred to as a myelogram. Essentially, the procedure involves introduction of a heavy, viscid contrast material into the spinal portion of the subarachnoid space. This injection is followed by fluoroscopic observation and radiographic recording of the contrast media flow around the spinal cord.

664. Name, locate, and describe major parts of the spinal cord.

Anatomic Considerations. The spinal cord is the longest and most inferiorly situated portion of the CNS. Essentially, it provides a means of communication between the brain and the nerve fibers connecting to the various parts of the body.

External structure of the spinal cord. As you can see in figure 5-1, the spinal cord is an extension of the brain stem. It joins the medulla oblongata in the region of the first cervical vertebra and then descends through

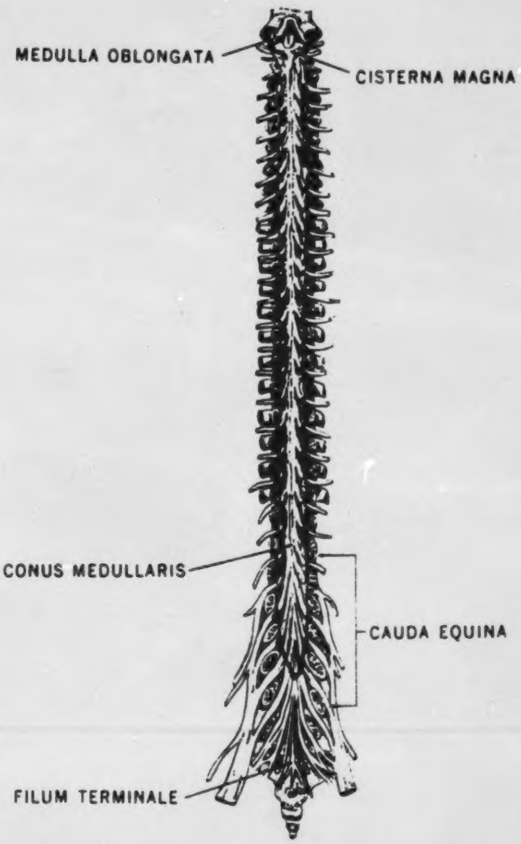

Figure 5-1. The spinal cord.

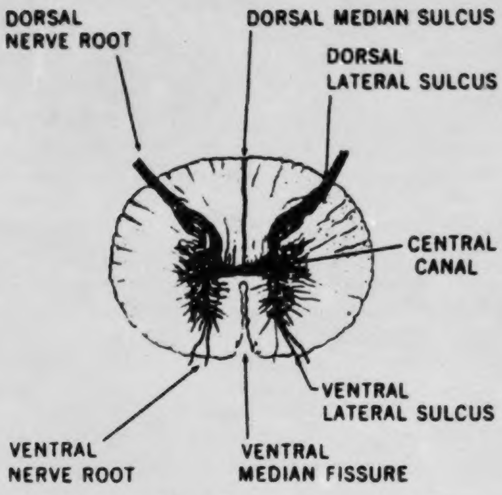

Figure 5-2. The dorsal and the ventral sulci.

the spinal canal to about the level of the first or second lumbar vertebra. The cord is approximately 42 to 45 centimeters long, about 1 centimeter in diameter, and is roughly cylindrical. It terminates in a sharply constricted cone called the conus medullaris. The filum terminale, a slender filament, extends from the apex of the conus to the first coccygeal segment where it is attached to the osseous tissue of the vertebral column.

The anterior, a ventral surface of the cord, is scored by a relatively deep fissure. This centrally situated depression is called the ventral median fissure. The posterior, or dorsal surface, is scored by a similar but much shallower depression called the dorsal medial sulcus. These major depressions divide the cord into lateral halves. Each half is further scored by two shallow furrows, referred to as the dorsal lateral sulcus and ventral lateral sulcus, respectively. Figure 5-2 illustrates the location of these grooves. The dorsal nerve roots pass through the dorsal lateral sulci and provide the posterior connection between the spinal nerve and the central portion of the cord. The ventral nerve roots pass through the ventral lateral sulci and serve to connect the anterior portion of the central part of the cord with the spinal nerve. Figure 5-3 illustrates the appearance of the nerve roots emanating from their respective sulci and joining to form the spinal nerves.

The spinal cord gives off 31 pairs of spinal nerves. As you can see in figure 5-1, the cervical and thoracic nerves exit transversely from the cord and those on the lumbar region descend almost vertically from the conus medullaris. Thus, the lumbar and sacral nerves descend individually from the conus to their respective points. This region, which extends from about the second lumbar vertebra to the second sacral segment, is referred to as the cauda equina, which means "horses tail." It is so named because the vertically situated lumbar and sacral nerves resemble the coarse hair in the tail of a horse. The spinal cord and cauda equina are completely invested by three layers of membranous tissue that we will discuss later in this chapter.

Internal structure of the spinal cord. Generally speaking, the inner portion of the spinal cord is comprised of an H-shaped column of gray matter and fiber tracts of white matter shown by the dark-shaded H and the lighter shaded material in figure 5-2. The gray matter forms the core of the cord and is surrounded by the white matter. Both types of tissue are continuous with that of the medulla oblongata. The cross section through the cord shows the structural relationship between the core and its surrounding tissue.

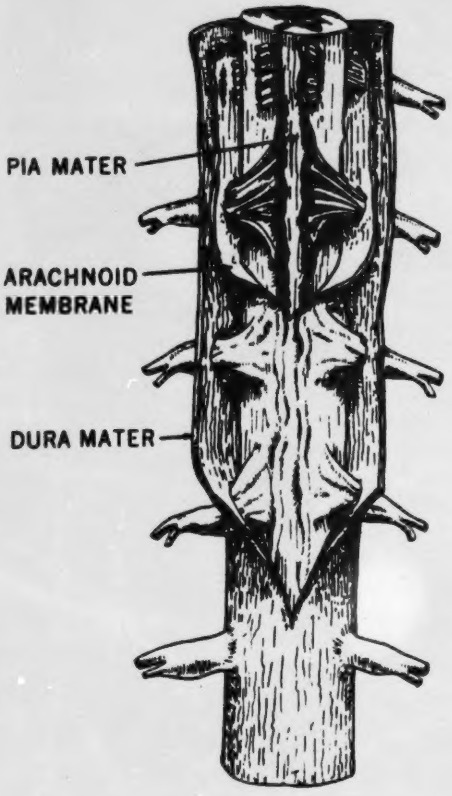

Figure 5-3. The nerve roots emanating from their sulci.

Exercises (664):

Fill in the blank spaces with one or two appropriate words.

1. The spinal cord connects with the medulla oblongata near the ___________ vertebra.
2. The spinal cord is about ___________ to ___________ cm long and about ___________ cm in diameter.
3. The end of the spinal cord is called the conus ___________.
4. The spinal cord is divided into lateral halves by the ___________ fissure and the ___________ sulcus.
5. A dorsal nerve root connects the ___________ to the center of the spinal cord.
6. The ___________ root connects the spinal nerve to the anterior portion of the spinal cord.
7. There are ___________ of spinal nerves given off by the spinal cord.
8. The ___________ is the region extending from about the second lumbar to the second sacral vertebra containing the vertically situated nerves.
9. Two types of tissue found in the spinal cord continuous with that of the medulla oblongata are the inner ___________ and the outer ___________.

665. Provide pertinent facts pertaining to the patient's position while contrast medium is introduced into the subarachnoid space of the spinal cord.

Radiographic Considerations. Basically, the myelogram consists of the radiologist introducing the contrast medium into the subarachnoid space followed by fluoroscopy and spot films. After that you usually will be required to take some post-fluoro radiographs, after which time the radiologist removes as much of the contrast material as possible. Your role generally consists of assisting the radiologist, as needed, and as we mentioned, making some radiographs.

Positioning the patient for lumbar puncture. The contrast medium is usually injected into the subarachnoid space of the spinal cord by means of a lumbar puncture. (Another injection site is occasionally used which we discuss later.) Depending upon your radiologist's preference, you should position the patient for the lumbar puncture on the X-ray table in the prone or lateral recumbent position. In either case, attach the headboard and footrest to the table because the radiologist tilts the table in both directions throughout the examination so the contrast material gravitates to certain areas in the spinal cord.

If the injection is to be accomplished with the patient prone, place a rolled pillow or other similar object under the patient's lower abdomen to straighten the lumbar lordosis so that the radiologist can more accurately locate the injection site. The space between the two spinous processes through which the injection is made is also widened, enabling the radiologist to make a more accurate puncture. If the injection is to be made with the patient in the lateral recumbent position, place enough suitable material under his lower thoracic and upper lumbar spines to place the spine parallel with the table. Also, have him flex his spine by drawing his knees up toward his chin and drawing his head and shoulders forward (the fetal position). These actions also aid the radiologist in locating the injection site and making the lumbar puncture.

Positioning the patient for the cisternal puncture. The contrast medium is rarely injected into the cisterna magna, the widest portion of the subarachnoid space, located in the upper cervical region between the base of the cerebellum and the medulla oblongata. Called a cisternal or cervical puncture, this procedure is somewhat dangerous and only used when the subarachnoid space is obstructed, preventing flow of the lumbar injected medium to the upper spine. For the cisternal puncture, place the patient in the lateral recumbent position. Elevate his head to place the cervical spine parallel with the table. Initially, until the injection is completed and the needle withdrawn, the patient's head is flexed and the head-end of the table is elevated. Immediately after injection the head is hyperextended, and usually held in place by another physician to prevent the contrast medium from entering into the ventricular system of the brain.

Exercises (665):

1. What two basic body positions are used for a lumbar puncture?

2. With which of the positions indicated in exercise number 1 above should you attach the footrest and headboard?

3. Why should you elevate the patient's lower abdomen for a prone lumbar puncture?

4. Why should the lower thoracic and upper lumbar vertebrae be elevated for a lateral lumbar puncture?

5. Describe the fetal position.

6. When is the cisternal puncture used in place of the lumbar puncture?

7. What basic body position is used for the cisternal puncture?

8. What is the position of the patient's head and the table during a cisternal puncture injection?

9. Why is the patient's head hyperextended immediately after the cisternal injection is completed?

666. Briefly describe the intraspinal pressure test using a manometer and the Queckenstedt sign.

Testing for intraspinal pressure. At times, the radiologist elects to check the amount of fluid pressure within the subarachnoid space before injecting the contrast material. Consequently, you should always have a Rubin's manometer available. The radiologist simply connects this device to the stopcock and allows cerebrospinal fluid to flow into the calibrated glass tube. The height to which the fluid rises indicates the amount of pressure within the subarachnoid space.

Also, he can look for the *Queckenstedt* sign that indicates whether or not there is an obstruction or block in the vertebral canal. For this procedure the radiologist needs your assistance. He will ask you to compress the veins of the neck on one or both sides and release the pressure upon his signal. Your radiologist will demonstrate the exact compression site and procedure. Sometimes when the veins are compressed, the pressure of the cerebrospinal fluid rises quickly if there is no obstruction. When the pressure is released, the pressure also drops quickly. If an obstruction is present, the pressure is usually not affected by the compression or release of the compression.

Exercises (666):

1. Briefly describe the test for intraspinal pressure using a Rubin's manometer.

2. Briefly describe the Queckenstedt sign.

667. Discuss the two dangers to the patient during a myelogram in terms of the consequences, and cite typical precautionary measures.

Injection of the contrast medium and fluoroscopy. Once the preliminary procedures are over, the radiologist injects the contrast medium. After that he replaces the stylette in the needle and covers the needle with a sterile dressing. The needle is left in place so that the contrast material can be removed when the examination is over. As indicated before, during a cisternal puncture the needle is removed after injection of the medium. In this case the medium is removed through a second puncture.

If the upper thoracic or cervical spinal canals are examined, an additional technician may be required to maintain the patient's head in an elevated and hyperextended position during fluoroscopy and until the medium is removed. Also, the patient's head must not be permitted to drop below the level of the spine. As indicated earlier, this is to prevent the contrast medium from entering the ventricles of the brain.

The patient is usually placed in the prone position for fluoroscopy, leaving the protruding needle between the patient's spine and the fluoroscopic apparatus. At this time you must lock the vertical adjustment of the fluoroscopic unit in place so that it cannot be accidently lowered to contact the needle. This event could result in the needle being driven into the spinal nerves, causing permanent paralysis of a portion of the patient's lower anatomy. Of course, your radiologist is also aware of the dangers involved with the protruding needle. However, because of the possible consequence, if both you and your radiologist "double-check" each other, the chance of farther insertion of the needle is minimized.

The fluoroscopic apparatus can be positively secured to prevent accidental contact with the needle by means of a commercial myelographic stop made especially to be used with certain X-ray machines. It is simply a metal bar which attaches to the fluoroscopic unit and maintains a certain amount of space between the unit and tabletop. This is the best method to use because it does not rely on a "lock" that can become defective.

Post-fluoro projections. When the radiologist terminates the fluoroscopy, he will more than likely require you to perform certain radiographs. There are two important factors to keep in mind while performing the radiographs. The first is that the needle is still present in the patient's back and must be prevented from contacting anything. The second is that the patient's head must not be permitted to drop below the level of the spine. If the contrast medium is in the thoracic or cervical spines, the hyperextension of the head must also be maintained.

The specific projection you make will depend upon your radiologist's fluoroscopic findings. However, PA, anterior oblique, and standard or cross-table lateral radiographs can be made. Obviously, you will not perform AP and posterior obliques due to the presence of the needle.

Exercises (667):

1. With respect to the patient's head, what precautions may have to be taken throughout the myelogram and why?

2. With respect to the protruding needle, what precautions should be taken and why?

5-2. Pneumoencephalography and Ventriculography

The brain is the largest and most complex part of the central nervous system. It is encased by the cranial bones and is divided into lobes for anatomical purposes. In this section, we discuss these characteristics of the brain and then consider the applicable radiographic procedures.

668. Name and describe significant parts of the cerebrum and the ventricular system of the brain.

Anatomic Considerations. As you can see in figure 5-4, the brain consists of the cerebrum, or forebrain; the midbrain; the cerebellum, or hind brain; and the brain stem. Let's look at them.

The cerebrum. The egg-shaped cerebrum is the largest component of the brain. As you can see in figure 5-5, it is divided longitudinally by a deep cleft called the longitudinal fissure. The two parts are referred to as hemispheres. Notice that the surfaces of these hemispheres are comprised of folded ridges (convolutions) called gyri. The gyri are separated from each other by shallow furrows called sulci. Six of the sulci, three in each hemisphere, are deeper than the others and serve to segment the cerebrum. These segments are referred to as lobes. Four of the lobes are named for the cranial bones which cover them, while the fifth is called the insula.

The convoluted surface of the hemispheres is comprised of gray matter (so-called because of its color). This gray matter spreads over an inner mass of specialized fibrous tissue called white matter (once again, after its color).

The midportion of the cerebrum houses four irregularly shaped, interconnected cavities referred to as ventricles (see fig. 5-6). The ventricles are lined with delicate tissues which secrete the lymph-like cerebrospinal fluid that fills the ventricles and the intracranial and spinal portions of the subarachnoid space. Each lateral ventricle (there are two) is comprised of a central portion, or body, and three appendages referred to as the anterior, posterior, and inferior horns. The majority of the body, including the anterior and posterior horns, is situated directly below the corpus callosum. The anterior horn extends into the frontal lobe and the posterior horn into the occipital lobe. Each lateral ventricle communicates with the third ventricle by a channel called the foramen of Monro.

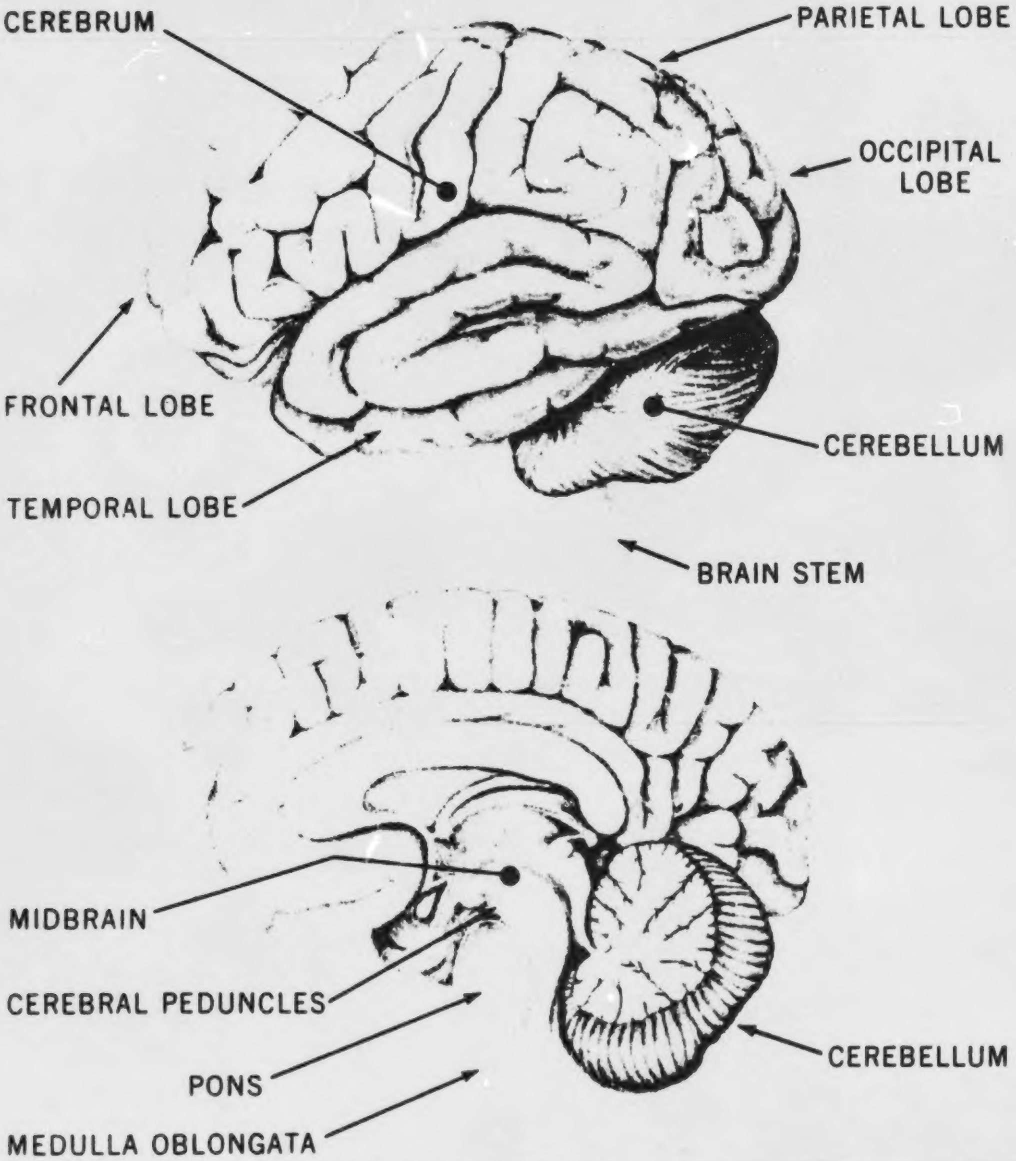

Figure 5-4. The component parts of the brain.

The third ventricle is situated in the midline, directly below the medial aspects of the lateral ventricles. It is housed between the masses of the thalamus, and its anterior-inferior portion extends downward through the hypothalamus. The third ventricle consists of a central portion from which irregularly shaped projections extend posteriorly and antero-inferiorly. The posterior portion is situated above the pineal body and, thus, is referred to as the suprapineal recess. The third ventricle communicates with the fourth ventricle through the aqueduct of Sylvius.

The rhomboid, or diamond-shaped fourth ventricle, is a midline structure situated in the space between the cerebellum and the brain stem. Its posterior aspect is formed by the concavity between cerebellar hemispheres. The fourth ventricle is continuous with the central canal of the spinal cord, which is the constricted inferior portion of the cavity. Other than the aqueduct of Sylvius there are three openings into the fourth ventricle—the

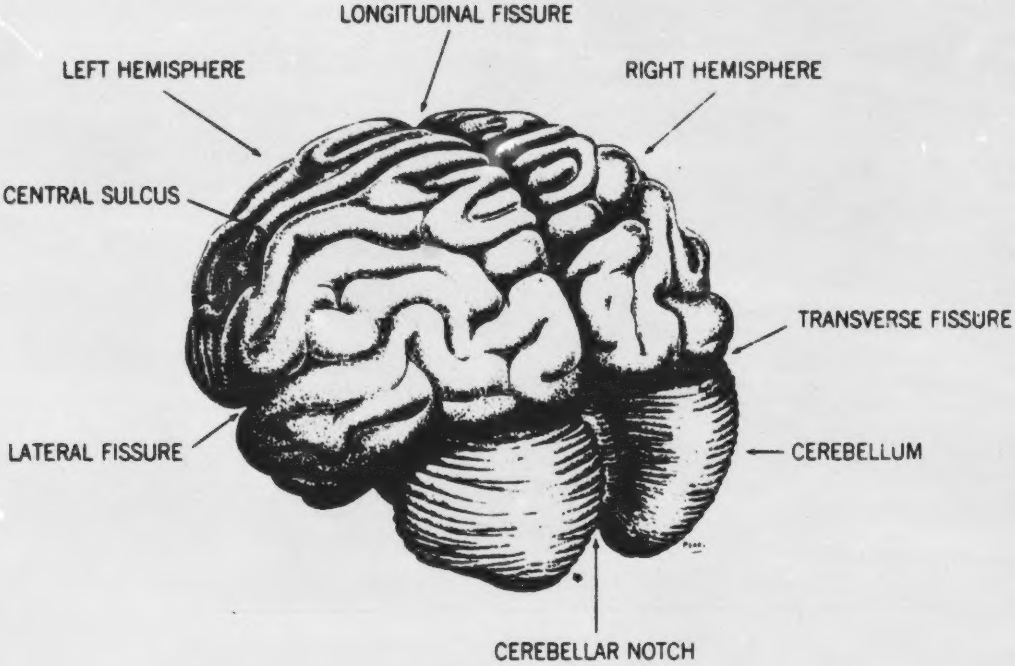

Figure 5-5. Relative positions of brain structures.

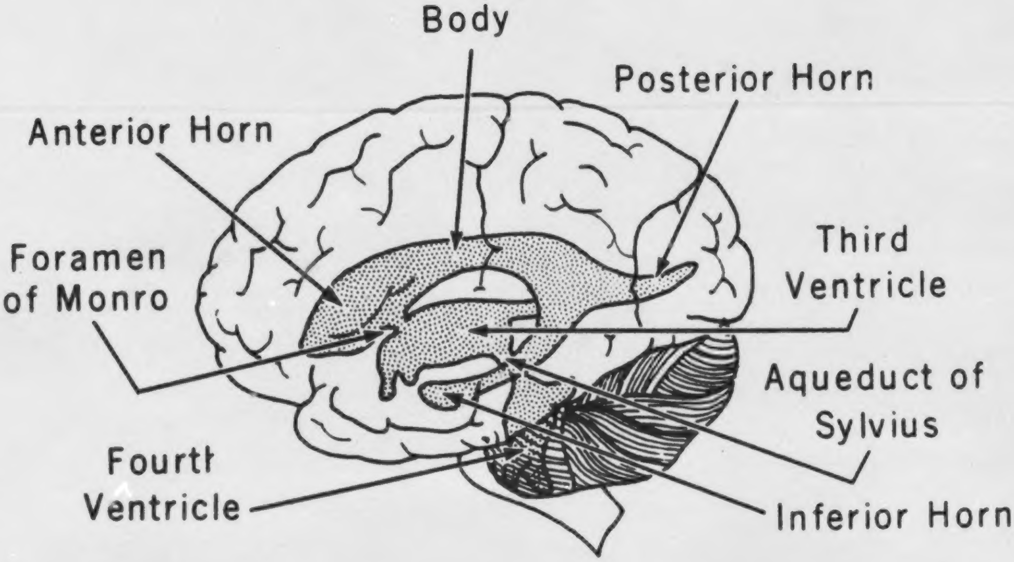

Figure 5-6. Ventricles of the brain.

foramen of Magendie and two foramina of Luschka. The ventricle communicates with the cisterna magna through the foramen of Magendie and with the subarachnoid cisterns through the two foramina of Luschka.

Exercises (668):

Fill in the blank spaces with one or more appropriate words.

1. The largest component of the brain is the ______________.
2. The cerebrum is divided into __________ and ______________ hemispheres by the ______________.
3. The folded ridges on the surfaces of the cerebrum are called ____________.
4. The names of the five cerebral lobes are _____________, ______________, __________, ____________, and ______________.
5. The outer layer of cerebral tissue is referred to as ______________.
6. Cerebrospinal fluid is secreted by the four ____________.
7. The two large "wishbone-shaped" ventricles are the ____________.
8. The foramina of Monro connect the _________ ventricles to the _______.
9. The posterior portion of the third ventricle is known as the ____________.
10. The fourth ventricle communicates with the third ventricle by the way of the ______________.
11. The fourth ventricle communicates with the cisterna magna by way of the __________________.

669. Name and locate significant features of the cerebellum and brain stem.

The cerebellum. The cerebellum, second largest component of the brain, is situated beneath the posterior aspect of the cerebrum (the occipital lobe). The cerebellum is comprised of a central stalk, called the vermis, and two hemispheres. The hemispheres are separated from the cerebrum by a deep cleft, called the transverse fissure. Their superior aspects are also separated from each other by a shallower vertical cleft, referred to as the cerebellar notch.

The brain stem. The midbrain, pons, and medulla oblongata are referred to as the "brain stem." As you can see in figure 5-4, these structures are united and are situated anterior to the cerebellum. (The medulla oblongata is actually continuous with the spinal cord, but for our purposes, we consider these structures as separate entities.)

The midbrain is a short, constricted segment connecting the pons and cerebellum with the cerebrum. The cerebral peduncles carry impulses between the cerebrum and spinal cord.

The pons (see fig. 5-4) is a large bulbous mass of fiber tracts situated below the midbrain, anterior to the cerebellum, and superior to the medulla oblongata. It is comprised primarily of white matter, although it does house the nuclei of four cranial nerves in its central portion.

The medulla oblongata (see fig. 5-4), often referred to as "the bulb," is actually an enlarged area of the spinal cord. It is situated below the pons and just above the foramen magnum. The anterior surface of the medulla oblongata is comprised of two bundles of fibers called the pyramids. The posterior aspects of the medulla houses two major nuclei which receive the fibers from the white columns of the spinal cord below and the thalamus and cerebellum above.

Exercises (669):

1. Where is the cerebellum located with respect to the cerebrum?
2. What are the names of the three basic parts of the cerebellum?
3. What are the three parts of the brain stem?
4. What parts of the midbrain carry impulses between the spinal cord and cerebrum?
5. Where is the medulla oblongata located?
6. What are the pyramids?

670. Provide significant features of the meninges and subarachnoid space.

The meninges. The brain and spinal cord are completely covered by three layers of membranous tissue which are referred to collectively as the meninges. They are comprised of the pia mater, arachnoid membrane, and the dura mater.

The pia mater is the innermost portion of the meninges. It is a highly vascular membrane which very closely covers the brain and spinal cord. The intracranial portion of the pia covers the gyri of the cerebrum and cerebellum; dips down into sulci of both structures; extends into the transverse cerebral fissure; forms the tela choroidea of the third ventricle, and, in part, the choroid plexuses of the lateral and fourth ventricles; and covers the outer surfaces of the corpus callosum, hypothalamus, mamillary bodies, pons, and medulla oblongata. The spinal portion of the pia mater is somewhat thicker than the intracranial portion. It completely encircles the cord and is closely adherent to it. The tissues of the pia completely fill the median fissure and form a sturdy band along its ventral margins. The pia extends into the filum terminate and blends with the dura mater (outer meningeal membrane) in the region of the second sacral segment where it joins the peritoneum.

The term "arachnoid" literally means spiderlike. Its use in connection with the meninges refers to the similarity between a spider's web and the delicate structure of the middle meningeal membrane. As you can see in figure 5-3, the arachnoid is situated between the pia mater and the dura mater. It loosely envelopes both brain and spinal cord. The arachnoid, unlike the pia, does not dip down into the sulci of the cerebrum and cerebellum. The arachnoid membrane is not closely adherent to the pia mater but is separated from it by the subarachnoid space. Cerebrospinal fluid, produced by the ventricular system, is circulated through this space. The subarachnoid space is not uniform in depth; the wide deep regions are referred to as cisterns. The three principal cisterns are located in the vicinity of the cerebral peduncles, the junction of the pons, and the medulla oblongata, and the inferior surface of the cerebellum and the brain stem. The spinal portion of the arachnoid loosely invests the cord and terminates in the distal reaches of the cauda equina.

The dura mater is the outermost meningeal membrane. Comprised of tough, fibrous tissue, the dura completely covers the outer surfaces of the brain and spinal cord. Its intracranial portion is comprised of two layers. The outer, periosteal layer, is in direct contact with the inner surfaces of the cranial bones. The smooth inner, or meningeal layer, overlies the arachnoid membrane. Both layers of the dura are joined except in the places where the dural sinuses pass between them. The meningeal layer of the dura is separated from the arachnoid membrane by the shallow subdural space. This space is similar to that found between the visceral and parietal layers of the pleura. It contains a small amount of fluid to prevent adhesion and friction.

The subarachnoid space. As previously described, the subarachnoid space is continuous around the brain and spinal cord, and is divided into intracranial and spinal portions. It is not uniform in depth. The deep spaces in the intracranial portion are referred to as cisterns and surround the base and stem of the brain. The largest of these is the cisterna magna. It actually forms a funnel around the base of the cerebellum and the medulla oblongata.

Exercises (670):

Fill in the blank spaces with one or two appropriate words.

1. The three layers of tissue surrounding the brain and spinal cord are called the ______ __________.
2. The inner meningeal layer is the ________.
3. The thicker portion of the inner meningeal layer is in the __________ area.
4. The inner meningeal layer blends with the outer layer near the _____________ vertebra.
5. The middle meningeal layer is the _____________ membrane.
6. The space between the middle and inner meningeal layers is called the _____________ space.
7. The space indicated in exercise number 6 above contains ______________.
8. Wide, deep portions of the subarachnoid space are called _____________.
9. The subarachnoid space ends in the distal portion of the _____________.
10. The outer meningeal layer is called the ___ _____________.
11. The two layers of the outer meningeal membrane are joined everywhere except in the locations of the __________.
12. The space between the middle and outer meningeal layers is called the __________.
13. The largest cistern is the ___________.

671. Compare pneumoencephalography with ventriculography.

Radiographic Considerations. Pneumonencephalography and ventriculography, also called intracranial pneumography, are two examinations performed to visualize the ventricles of the brain filled with a contrast medium. Basically, the examinations are similar with respect to the projections made after the medium is introduced. However, there is a considerable difference between the two to that point.

Comparison of pneumoencephalography and ventriculography. The entire pneumoencephalographic procedure is accomplished in the radiology department. The examination usually begins with patient seated with his forehead resting against an upright filming device, such as a head unit, upright X-ray table, or other upright bucky. He can be strapped into a special pneumoencephalographic chair, or if one is not available, he can be seated astride a standard straight-backed chair. The physician usually makes a lumbar puncture (rarely a cisternal puncture) and, after removing a small amount of spinal fluid, replaces it with air, carbon dioxide, or oxygen. Since air rises, the negative contrast medium ascends the spinal cord and for the most part enters the ventricular system of the brain. (A small amount of medium also enters the subarachnoid spaces of the brain.)

The surgeon then asks for an AP or lateral projection or both to determine whether or not the contrast medium does, in fact, reach the ventricular system. Make these initial projections without moving the patient except to turn his head for the lateral, if it is necessary to do so. After inspecting the radiographs, the surgeon usually administers more contrast medium and asks for additional scout films. When he is satisfied that the ventricles are sufficiently filled, he will ask you to perform the standard projections.

The contrast medium for the ventriculogram is introduced in the operating room; consequently, you may be required to perform the scout films there with the portable unit. After the patient is anesthetized, the surgeon, using a special trephine saw which is used to remove a circular disc of bone, makes a small hole on each side of the skull (usually called trephine openings). If the patient is an infant, the holes may not be necessary due to the open sutures or anterior fontanel. The surgeon then inserts a needle through each opening into the lateral ventricles and replaces a certain amount of the spinal fluid with the same type of contrast media used for pneumoencephalography. If the surgeons want scout films, an AP or PA and cross-table lateral projections are usually made. After inspecting the radiographs, the surgeon can introduce more of the contrast medium; or he can remove the needles, dress the wounds, and have the patient transferred to the radiology department for the radiographs.

Exercises (671):

Match the radiographic examination in column B with the appropriate statement in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, both column B items may match a single column A entry.

Column A

_ 1. First radiographs are made with the patient upright.
_ 2. The contrast medium is introduced through trephine openings.
_ 3. The contrast medium, during introduction, rises into the ventricles.
_ 4. The examination visualizes the ventricles of the brain.
_ 5. Some contrast medium enters the subarachnoid space of the brain.
_ 6. Patient is seated for introduction of the medium.
_ 7. Scout films include a cross-table lateral.
_ 8. Contrast medium is introduced directly into the lateral ventricles.

Column B

a. Pneumoencephalography.
b. Ventriculography.

672. Give essential facts pertaining to the welfare of the patient and the importance of patient cooperation and technician speed during intracranial pneumography.

Preliminary considerations. Intracranial pneumography is perhaps the most hazardous and uncomfortable neuroradiological procedure you will perform. In addition, the success of the examination depends, to a great extent, on the speed and exactness by which you perform the radiographs. Following these considerations, we discuss some preliminary aspects and thoughts which will help you perform your part in the examination.

During intracranial pneumography, the patient is likely to experience conditions, such as hypotension, headaches, restlessness, nausea or vomiting. Also, a more severe condition, such as respiratory arrest, can occur. Accordingly, you should have the appropriate emergency equipment available. If your emergency supplies are on a cart, as we discussed in chapter 2, it should be brought into the room. Specifically, such items as the AMBU, oxygen, suction apparatus, laryngoscope, blood pressure cuff, and intravenous fluids might be needed. Hypotension is a common condition and for that reason some surgeons want the patient's blood pressure monitored throughout the examination. Some physicians also want the patient's legs wrapped tightly with elastic bandages to minimize fluctuations in the blood pressure.

Due to the discomfort of the patient, it is often difficult to achieve the desired head positions for the radiographs. In fact, the accuracy of the positions is usually directly related to the extent to which the patient cooperates. Therefore, you should make a positive attempt to inspire his cooperation and confidence. As we have mentioned several times before, one way to gain the patient's help is to explain the examination to him in advance. Stress the importance of the accuracy of the positions and describe each position to him. Throughout the examination, show that you are visibly and actively concerned with his comfort and well being. Praise him after each projection. Keep in mind that the degree to which he cooperates depends, in part, upon *your* actions—so act accordingly.

Another consideration to which you should give thought is to perform the radiographs quickly. One obvious reason for this is the patient's discomfort. The quicker you finish the radiographs, the quicker he can return to the comfort of his bed and begin recuperation. Another reason speed is essential is that absorption of the contrast medium begins almost immediately. Therefore, if you take too long to perform the radiographs, the amount of the medium remaining may be insufficient to adequately visualize the structures.

A minimum of two technicians should perform the radiographs during intracranial pneumography for the reasons stated above. Also, make sure that you have enough cassettes or grid cassettes available to complete the examination without delay.

Exercises (672):

1. List six possible adverse effects that the patient might experience during intracranial pneumography.

2. List six emergency treatment items that should be readily available.

3. Why should the patient's legs be bound?

4. Why should you gain the patient's confidence and cooperation?

5. How can you help gain the patient's confidence and cooperation?

6. Why should you perform the radiographs quickly?

673. Answer key questions pertaining to the projections made during intracranial pneumography.

Projections. The projections you will perform during intracranial pneumography depend upon the preference of your radiologist and surgeon and the reasons for which the examination is performed. Most of the projections will be performed with the median plane either perpendicular or parallel to the film. These relationships are very important to the correct diagnosis of a space occupying lesion. If the relationships are not maintained, a space occupying lesion may be obscured or the outline of the ventricles may simulate a lesion that does not exist.

Most radiologists want you to perform two or more projections from a basic head position without moving the patient. For example; if from the brow-down position he wants a PA with a vertical C.R. and a lateral with a horizontal C.R., perform both projections without moving the patient's head. (NOTE: He may require two or three PAs made from the brow-down position with different C.R. angles and a horizontal lateral. Likewise, perform all of these projections without moving the patient.) The reason for this is so he can evaluate the anatomy from right angle aspects without a change in the distribution of the medium. Since the medium may shift its position with but little patient movement, the only way to satisfy the radiologist's desire is to take both projections with the patient maintaining his position.

As a rule, several projections are made of the airfilled ventricles by changing the position of the patient's head and the orientation of the C.R.. Several radiographs are needed because the surgeon does not completely fill the ventricular system with the contrast medium. He only fills a portion of the system. Therefore, to visualize the four ventricles and related structures, it is necessary to make several projections after the contrast medium shifts its position.

Usually, you will employ four basic head positions to obtain the radiographs: (1) brow-up, (2) brow-down, (3) standard lateral, and (4) extension. At least two, and sometimes more, projections are made from each position.

In the brow-up position, the patient is supine on the table with his median plane perpendicular to the table. Also, adjust his orbitomeatal lines perpendicular to the table. Several radiographs can be made from this position including an AP projection with the C.R. vertical and directed midway between the hairline and supraorbital ridge, and AP projections with the C.R. angled up to 30 degrees caudally and up to 10 degrees toward the head. A lateral projection using a horizontal C.R. (cross-table lateral) is also made with the patient in the brow-up position, in which case you should direct the C.R. to a point just superior to the superior border of the ear. The C.R. should be perpendicular to, and the median plane parallel with, the film. The interpupillary line should also be perpendicular to the film.

The brow-down position is similar to the brow-up except that the patient is prone instead of supine. The orientation of the median plane and orbitomeatal lines are the same as in the brow-up position. Some radiologists want you to elevate the head-end of the table 10° before placing the patient in the brow-down position and to keep it elevated for all the brow-down projections. The reason for the elevated table is to prevent the escape of air from certain critical locations within the ventricular anatomy. Brow-down radiographs include a PA with the C.R. vertical and passing through a transverse plane 2 inches superior to the external auditory meatus. A PA projection with the C.R. angled 25° cephalic and entering at the external occipital protuberance is also performed. A cross-table lateral projection is also made using the same guidelines as for the lateral brow-up projection.

With the standard lateral position, the head is positioned as you would for a "routine" lateral skull (semiprone), with the median plane parallel with, and the interpupillary line perpendicular to, the film. Adjust the vertical C.R. so that it enters one and one-half inches cranial to the external auditory meatus. Both laterals are usually made. AP or PA projections may also be made with the patient in this position, using a horizontal C.R.. Be sure the C.R. is perpendicular to the film.

Extension of the head refers to a position similar to that used for an inferosuperior projection of the skull. The patient is supine on the table with his head either hanging off the end of the table with the vertex resting on a support, or his shoulders are elevated to the extent that the vertex can be placed on the X-ray table itself. The head must be extended and positioned so that the orbitomeatal line is horizontal. A lateral projection with a horizontal C.R. is usually made from this position. Direct the C.R. through the sella turcica.

Sometimes the third and fourth ventricle can only be demonstrated with a lateral tomogram. While this tomogram can be made with a tomographic apparatus, at times the apparatus cannot be used due to the position of the patient's head. For example, some radiologists want the tomogram upright immediately after the injection during a pneumoencephalogram. If you cannot use the tomographic apparatus, perform an autotomogram as follows: Position the head so that the median plane is parallel with, and the interpupillary line is perpendicular to, the film. The film itself is vertical and the C.R. is horizontally directed to a point 1 inch anterior to, and 1 inch superior to the external auditory meatus. Have the patient rock his head gently through a 10° arc as if shaking his head "no." Using his forehead as the pivot point, use a 2½-second exposure.

Exercises (673):

1. Why is it important to position the head with the proper median plane to film relationships?

2. Why should some radiographs be made without moving the patient's head between exposures?

3. Why are several projections made by changing the patient's head position and the orientation of the C.R.?

4. How is the orbitomeatal line and median plane positioned for the brow-up positions and brow-down positions?

5. To what part of the patient should the C.R. be directed for an AP projection (vertical C.R.) made with the patient in the brow-up position?

6. To what part of the patient should the C.R. be directed for horizontal laterals made with the patient in the brow-up or brow-down position?

7. Why should the head-end of the table be elevated 10° while the patient is in the brow-down position?

8. To what part of the patient is the C.R. directed for lateral projections made with a vertical C.R.?

9. Briefly describe the extension position of the head.

10. What projection is usually made from the extension position?

11. Why is a lateral tomogram sometimes performed?

12. To what part of the patient is the C.R. directed for a lateral autotomogram?

13. What is the position of the patient's head with respect to the film for an autotomogram?

14. How should the patient move his head during an autotomogram?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:
600 - 1. Hard and soft palates.
600 - 2. Maxillae and palatines.
600 - 3. Elevation of the soft palate separates the nasal cavity and nasopharynx from the oral cavity and oropharynx.

601 - 1. c.
601 - 2. b.
601 - 3. b.
601 - 4. a, b, c.
601 - 5. a, c.
601 - 6. a.
601 - 7. a, c.
601 - 8. b.
601 - 9. c.
601 - 10. c.
601 - 11. c.
601 - 12. b.

602 - 1. T.
602 - 2. F. It is the proximal portion,
602 - 3. F. Food and air pass through the oropharynx.
602 - 4. T.
602 - 5. T.
602 - 6. T.
602 - 7. T.
602 - 8. F. It is approximately 25 cm long.
602 - 9. T.
602 - 10. F. It is posterior to the heart.
602 - 11. T.

603 - 1. Greater curvature. Lesser curvature.
603 - 2. On the greater curvature.
603 - 3. Incisura angularis.
603 - 4. (1) Cardiac orifice - lies at the level of the eleventh thoracic vertebra 1 inch to the left of the lateral sternal border. (2) Pyloric orifice - 1 to 2 inches to the right of the midline at the level of the upper border of the first lumbar vertebra.
603 - 5. (1) Fundus - proximal. (2) Body - middle. (3) Pylorus - distal.
603 - 6. The iliac crests.
603 - 7. Hypersthenic or obese.
603 - 8. Asthenic.
603 - 9. Two to 4 inches below the level of the iliac crests.
603 - 10. Like a "J."

604 - 1. Duodenum, 25 cm; jejunum, 7 to 8 feet; and ileum, 16 feet.
604 - 2. Oblique.
604 - 3. When the bulb lies in an anteroposterior direction.
604 - 4. It marks the end of a small bowel series when it is visualized on a radiograph.
604 - 5. Duodenum. Posterolaterally from the pylorus. Curves downward and descends over the head of the pancreas, curves medially and upward behind the stomach and finally curves sharply downward.
604 - 6. The proximal half of the duodenum.

605 - 1. Cecum, ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, sigmoid colon, rectum, anal canal, and anus.
606 - 1. Hemidiaphragm.
606 - 2. Right; quadrate; caudate.
606 - 3. Falciform ligament.
606 - 4. Inferior.
606 - 5. Common hepatic.
606 - 6. Posterior; duodenum.
606 - 7. Intrahepatic radicals.
606 - 8. Cystic.
606 - 9. Common bile; pancreatic.
606 - 10. Common bile; pancreatic.
606 - 11. Duodenal papilla.
606 - 12. Tail, body, head.
606 - 13. Islets of Langerhans.
606 - 14. Duct of Santorini.

607 - 1. To intensity or amplify the brightness of the fluoroscopic image.
607 - 2. (1) X-rays strike the input phosphor causing it to emit light photons. (2) The light photons strike the photocathode causing it to emit photoelectrons. (3) The electrons are accelerated and focused so that they strike the output phosphor where they are converted to light photons.

608 - 1. Minification increases the brightness of the fluoroscopic image because the image displayed by the output phosphor is smaller than that of the input phosphor. Even though both phosphors contain the same total amount of light, the brightness of the output image is greater because the light is more concentrated.
608 - 2. The energies of the electrons across the tube are increased. The higher the electron energies, the more light photons emitted when the electrons strike the output phosphor.
608 - 3. Answer: 2,560.

Explanation: Minification gain $= \frac{(d_1)^2}{(d_2)^2}$

$= \frac{64}{1}$

$= 64$

Brightness gain = minification gain × flux gain
= 64 × 40
= 2,560

609 - 1. Two.
609 - 2. Conventional fluoroscopy.
609 - 3. You see the image with the rods on your retina (scotopic vision). Rods are very sensitive to light but cannot perceive fine detail.
609 - 4. You see the image with the cones on your retina (photopic vision). Cones allow you to resolve fine detail.

610 - 1. To enlarge and present the image to the viewer.
610 - 2. Two.
610 - 3. It must be in a specific area. If the head if moved only a few degrees, the viewer cannot see the fluoroscopic image.

611 - 1. The diameter of the input phosphor.
611 - 2. The 9-inch tube shows less detail around the periphery because of the distortion caused by the divergence of the electrons as they approach the output phosphor.
611 - 3. One in which the mode can be quickly changed by the fluoroscopist.
611 - 4. The image is slightly magnified on the input phospher due to the divergence of the primary beam.

612 - 1. It required an excessive dose of radiation to the patients.
612 - 2. The arrival of the image tube.
612 - 3. A special mirror designed to reflect 5 percent to 10 percent of the light from the output phosphor to the viewer and transmit the remaining 90 percent to 95 percent of the light to the cine camera.
612 - 4. The increased radiation required for cine increases the brightness of the image.

613 - 1. T.
613 - 2. F. It is the shutter.
613 - 3. T.
613 - 4. F. It is accomplished by the pressure plate.
613 - 5. F. It results in uneven frame densities when a single-phase generator is used.
613 - 6. T.
613 - 7. T.
613 - 8. T.

614 - 1. The statistical fluctuation of the X-ray photons.
614 - 2. The less the quantum mottle, the greater the resolution.
614 - 3. 35-mm because it requires a higher exposure.
614 - 4. It doesn't matter. Because all cine films have higher resolution capability than image tubes.
614 - 5. Detail.
614 - 6. Low.

615 - 1. The position of the viewer's head is not critical. Also, several persons can view the image simultaneously and monitors may also be placed outside the fluoroscopic room to be viewed by students and others.
615 2. Expense in purchase and upkeep. The fluoroscopic image lacks the quality of an image tube.
615 - 3. (1) Advantage - instant replay. (2) Disadvantage - the video tape image lacks the quality of cine image.

616 - 1. The presence of food, liquids, gas, or fecal material may result in difficulties in interpretation due to confusing shadows.
616 - 2. (1) Keep them consistent for the same examination. (2) Make them clear and easy to understand. (3) If a laxative is included, provide the nature of its action. (4) Specify goods allowed. (5) Include the phone number of your department.
616 - 3. Ask the patient if he followed the instructions before he is readied for the examination. You can save all persons concerned a lot of time.

617 - 1. They adhere to the mucosa of the pharynx and esophagus for a long time, allowing you to better "catch" the medium in the right area.
617 - 2. That specified by your radiologist.
617 - 3. Micronized and ionized powder. The metal can provide a conducting pathway and result in neutralization of the ionized particles. Also, the suspension property of the powder can be neutralized, causing the powder to settle out of suspension quicker.
617 - 4. Restir the preparation because some settling occurs in most preparations.
617 - 5. Oral Hypaque and Gastrografin.
617 - 6. To provide an air-contrast study of the fundus of the stomach.
617 - 7. It must be safe with respect to the lungs.
617 - 8. Your radiologist.

618 - 1. To locate and explore the main salivary duct.
618 - 2. Blunt needle.
618 - 3. (1) To stimulate the gland, permitting the duct opening to be located due to the discharge of saliva. (2) To evacuate the contrast material after the filled radiographs are made.
618 - 4. All of them.
618 - 5. Either PA or AP.
618 - 6. From 25° to 30° or until the area is perpendicular to the film.
618 - 7. The parotid.
618 - 8. Sublingual.
618 - 9. To the right.
618 - 10. From 10° to 30° cephalic.

619 - 1. The barium descends very quickly during the act of swallowing, and the patient can not respond promptly to your instruction to "swallow."
619 - 2. Observe the patient's thyroid cartilage during the act of swallowing. When it reaches its most anterosuperior position, make your exposure.
619 - 3. It permits a more unobstructed view of the distal esophagus.

619 - 4. The patient continuously drinks liquid barium from a straw. The exposure is made after 4 to 5 seconds of drinking.
619 - 5. The drinking esophagram usually shows the entire esophagus filled with barium. The others do not.
619 - 6. The visible size of the heart and pulmonary structures are also evaluated.
619 - 7. To minimize magnification of the heart.
619 - 8. It requires more rotation to project the heart clear of the spine because the heart is slightly to the left of the midline.
619 - 9. Commercial barium paste with special coating characteristics.
619 - 10. (1) Personal preference, (2) thickness of the medium, and (3) cooperation of the patient.
619 - 11. To permit visualization of the lower esophagus through the superimposed shadow of the heart.
619 - 12. To evaluate displacement of the esophagus by the great vessels of the heart.

620 - 1. Right anterior; right lateral; peristalsis.
620 - 2. Mucosa.
620 - 3. Walls.
620 - 4. Contrast medium; drug.
620 - 5. Respiratory muscles; artificial respiration.
620 - 6. LPO.
620 - 7. Pylorus; duodenal bulb.
620 - 8. Maximum peristalsis.
620 - 9. Right lateral.
620 - 10. Retrogastric structures.

621 - 1. a.
621 - 2. d.
621 - 3. c.
621 - 4. b.
621 - 5. a.
621 - 6. d.
621 - 7. c.
621 - 8. d.
621 - 9. b.
621 - 10. b.
621 - 11. a.

622 - 1. During the direct method, barium is introduced followed by air. During the two-stage method the barium is partially evacuated before air is introduced.
622 - 2. It must allow you to switch immediately from barium to air.
622 - 3. Yes.
622 - 4. Air pressure.
622 - 5. The long side is down. One of the two short sides is down.

623 - 1. F. The temperature is as specified by your radiologist and may be 41 F, about 85° F, or warmer.
623 - 2. T.
623 - 3. F. You should mix it immediately before use whenever possible, but you may not be able to do so always. The important factor to remember is that you must maintain the liquid at the correct temperature until use.
623 - 4. T.
623 - 5. T.
623 - 6. F. The opposite is true.
723 - 7. T.
623 - 8. F. It tells you whether or not the solution runs freely and prevents air from being introduced into the colon ahead of the barium.

624 - 1. To the iliac crest.
624 - 2. Take two films crosswise instead of a single film lengthwise.
624 - 3. To recoat the walls of the colon with barium.
624 - 4. Splenic flexure, hepatic flexure, and sigmoid colon.
624 - 5. LPO or RAO. RPO or LAO.
624 - 6. Center a coronal plane 2 inches posterior to the midaxillary line to the center of the table. Direct the C.R. perpendicularly through a point on the coronal plane 2 inches superior to the symphysis pubis.
624 - 7. (1) LPO—C.R. 30° to 35° cephalic.
(2) AP—C.R. 30° to 35° cephalic.
(3) PA—C.R. 30° to 35° caudad.
624 - 8. Sigmoid colon and rectum.
624 - 9. Approximately the same as that for a lateral rectum.
624 - 10. To demonstrate air/fluid levels.
624 - 11. Less than normal because of the radiolucency of the air.

625 - 1. From the spine to the lateral abdominal wall and from the right eighth rib to the iliac crest.
625 - 2. High in the abdomen near the lateral wall. Low in the abdomen near the spine.
625 - 3. 6 x 6 inches.
625 4. At the level of the 10th posterior rib, midway between the spine and lateral abdominal wall.
625 - 5. To be able to accurately project the gallbladder in a small cone field.
625 6. Nonvisualization.
625 - 7. To make sure the gallbladder is not on the opposite side and to check the stomach, small bowel, and large bowel for the contrast medium.
625 - 8. To visualize concentrated stones heavier than bile than gravitate to the dependent portion of the gallbladder; and to visualize layered stones that are lighter than bile.
625 - 9. One to 2 inches; 2 to 4 inches.
625 - 10. To prevent its superimposition over the spine.
625 - 11. Use PA or oblique Trendelenburg positions and obliques with more or less than 45 degrees of rotation.
625 - 12. The stones may leave the gallbladder, becoming lodged in the cystic or common bile duct.

626 - 1. b, c, d.
626 - 2. c.
626 - 3. b.
626 - 4. c. d.
626 - 5. a.
626 - 6. a.

CHAPTER 2

627 - 1. T.
627 - 2. F. 2.5 to 3 cm thick.
627 - 3. T.
627 - 4. T.

627 - 5. T.
627 - 6. F. They are located on the superior and medial aspects of the upper portions of the kidneys.
627 - 7. F. The 12th usually does so, the 11th only occasionally.
627 - 8. F. The renal hilum.
627 - 9. T.
627 - 10. T.
627 - 11. T.
627 - 12. T.
627 - 13. F. After leaving the minor calyces, it flows into the major calyces.
627 - 14. T.

628 - 1. 28 to 34.
628 - 2. Abdominal and pelvic.
628 - 3. Anterior to the transverse processes of the first and second lumbar vertebrae.
628 - 4. Pelvic.
628 - 5. Middle (muscular).
628 - 6. (1) Longitudinal fibers, (2) circular fibers, and (3) longitudinal fibers.

629 - 1. The inferior portion of the bladder is posterior to the symphysis pubis. The entire bladder is anterior to the rectum.
629 - 2. (1) External serous coat; (2) muscle tissue; (3) submucous coat; and (4) mucous-membrane lining.
629 - 3. By expansion of the muscular walls.
629 - 4. A triangular area in the postero-inferior bladder wall.
629 - 5. It (the trigone) is not as expansive.
629 - 6. In the upper, outer regions of the trigone.
629 - 7. As the bladder fills and stretches, the trigone stretches and clamps the distal ends of the ureters.
629 - 8. Internal urethral orifice.
629 - 9. It opens and closes the urethral orifice.
629 - 10. Prostatic, membranous, and cavernous.
629 - 11. Prostate.
629 - 12. Cavernous.
629 - 13. 4 cm.

630 - 1. To be able to recognize a possible serious reaction and advise your radiologist immediately.
630 - 2. Technique reaction.
630 - 3. (1) Pain at the injection site; (2) hematoma; (3) burning at the injection site or along the upper arm; and (4) numbness at the injection site or along the upper arm.
630 - 4. No. No.
630 - 5. They may be initial manifestations of more severe reactions.
630 - 6. (1) Hypertension; (2) hypotension; (3) weak, rapid pulse; (4) irregular pulse; (5) cardiac arrest; (6) cyanosis; and (7) unconsciousness.
630 - 7. (1) Urticaria (hives); (2) tightness of the chest; (3) sneezing; (4) wheezing; (5) itching; (6) watery or reddened eyes; (7) labored breathing; (8) high respiration rate; (9) low respiration rate; and (10) absence of respiration.
630 - 8. To begin with, keep in mind that we are only referring to the "mild" reactions with this question. You should always notify your radiologist immediately if the patient is experiencing a severe reaction. Whether or when you call him for other than severe conditions is something you should discuss with him. He may want to be notified of any reaction or he may not.

631 - 1. So they will be readily available.
631 - 2. So the equipment can be easily transported from one room to another.
631 - 3. So they can be quickly located. It also helps you to spot a "missing" item during inventory.
631 - 4. Daily.
631 - 5. (1) Expiration dates; (2) laryngoscope light; (3) proper operation of the suction apparatus; and (4) oxygen supply.
631 - 6. So they can locate them quickly.

632 - 1. To provide air or oxygen to patients if breathing stops or is difficult.
632 - 2. After proper OJT and as part of a preconceived plan with your radiologist.
632 - 3. (1) Tilt the patient's head back and lift his jaw forward; (2) hold the mask firmly against his face with your thumb and index fingers, keeping his chin and head back with your other three fingers; (3) squeeze the bag with your other hand; (4) release the bag and let the patient exhale. Repeat every three seconds—one second for inhalation, two seconds for exhalation.
632 - 4. By connecting an oxygen hose to the input nipple of the AMBU.
632 - 5. A catheter.
632 - 6. Depress them with your foot one-third to one-half down—maintain a constant rhythm with your foot.
632 - 7. To insert an endotracheal tube.
632 - 8. To connect the AMBU to the endotracheal tube.
632 - 9. Yes.

633 - 1. Child; age.
633 - 2. 0.5 cc; 1.0 cc; kilogram.
633 - 3. 23.
633 - 4. Over each scapula or into each gluteal muscle.

634 - 1. It prevents dilution of the contrast medium, allowing better visualization of the bladder, and it reduces the chance of a ruptured bladder during compression because of distention.
634 - 2. (1) It allows the radiologist to check for gas and fecal material which may interfere with the examination; (2) it provides the radiologist the chance to see a stone or other abnormality that may be obscured later by the contrast medium; and (3) it enables you to check your exposure and positioning.
634 - 3. The upper margins of the kidneys and superior portion of the symphysis pubis.
634 - 4. (1) Have the patient flex his knees to place the lower back in contact with the table, and (2) elevate the patient's head and shoulders slightly.

635 - 1. 25 to 30 degrees.
635 - 2. To evaluate gravitational emptying of the calyces and pelves and to evaluate the mobility of the kidneys.
635 - 3. To check bladder retention in males and females and to reveal prostate enlargement in males.
635 - 4. Those suspected of having a urinary stone.

635 - 5. Better outlining of the renal calyces and pelves and better demonstration of the ureters.
635 - 6. Across the upper pelvis at the level of the anterosuperior iliac spines.
635 - 7. So that the pressure is consistent from the examination to the next.
635 - 8. From 90 to 110 mm of mercury.
635 - 9. Place the patient in the Trendelenburg position—10° to 20°.

636 - 1. (1) It distends the stomach with gas, displacing the bowel downward and away from the kidneys; and (2) it provides excellent contrast between the kidneys and gas bubble in the stomach.
636 - 2. Two ounces to an infant—12 ounces to an 8-year old and proportionate amounts for ages in between.

637 - 1. Narrowing of a renal artery.
637 - 2. Visualization of the contrast material may be delayed when compared to that of the opposite kidney.
637 - 3. Rapid injection—radiographs are made at 30-second to 1-minute intervals.
637 - 4. Part of a hypertensive IVP performed to determine if the contrast medium "washes out" of one kidney faster than the other.

638 - 1. T.
638 - 2. T.
638 - 3. F. They should be centered to the level of the depression above the greater trochanter.
638 - 4. T.
638 - 5. F. Only when there is a loss of the normal lumbar lordosis. Otherwise, angle the tube 5° caudally.
638 - 6. T.
638 - 7. F. It is vertical—and strikes the film at a 15° to 20° angle.
638 - 8. T.
638 - 9. T.
638 - 10. T.
638 - 11. T.
638 - 12. F. The radiographs are usually made erect.
638 - 13. T.

639 - 1. Rectum.
639 - 2. Fundus.
639 - 3. Lateral; body.
639 - 4. Laterally; 12.
639 - 5. Fimbria; ovaries.
639 - 6. 4; 2; 8.

640 - 1. To evaluate patency of the fallopian tubes in cases of sterility.
640 - 2. Same answer as in exercise number 1 above.
640 - 3. The reason is most likely to document the presence of air (carbon dioxide) in the peritoneal cavity. Do an erect chest or abdomen to include the diaphragms.
640 - 4. To reduce the possibility of a filled bladder impinging upon the fallopian tubes and to prevent the bladder shadow from interfering with visualization of the contrast medium.
640 - 5. So that it flows more freely.
640 - 6. (1) Use two technicians; (2) prepare the cassettes with markers in advance; and (3) work quickly.
640 - 7. Two inches superior to the symphysis pubis.

CHAPTER 3

641 - 1. Trachea.
641 - 2. Cricoid; thyroid.
641 - 3. Epiglottis.
641 - 4. Anterior.
641 - 5. Fifth.
641 - 6. Cilia; secretions.
641 - 7. Rings; posteriorly.
641 - 8. Right; left.
641 - 9. Left; left; right.

642 - 1. Two. Three.
642 - 2. Lobar bronchi.
642 - 3. Tertiary or segmental bronchi.
642 - 4. After the tertiary bronchi.
642 - 5. Alveolar ducts.
642 - 6. Alveoli.

643 - 1. Mediastinum.
643 - 2. A triangular depression on the inner medial surfaces of each lung where the blood vessels and nerves enter and leave the lung.
643 - 3. One to 1½ inches above the level of the sternoclavicular joint, bilaterally.
643 - 4. The diaphragm.
643 - 5. Three. Two.
643 - 6. Fissures.

644 - 1. d.
644 - 2. a.
644 - 3. a.
644 - 4. a, d.
644 - 5. b.
644 - 6. c.
644 - 7. b.
644 - 8. d.
644 - 9. d.

645 - 1. The examination may not be successful.
645 - 2. (1) The patient may cough up the contrast material. (2) Coughing may create peripheral flooding, which results in difficulty in interpretation.
645 - 3. (1) Explain the examination to him. (2) Stress the importance of his not coughing. (3) Instruct him to pant if he feels the urge to cough.
645 - 4. Use two technicians and work *quickly*.

646 - 1. Three. PA or AP, lateral, and oblique.
646 - 2. RPO or LAO.
646 - 3. LPO or RAO.
646 - 4. To project the lung free from superimposition by the spine.
646 - 5. One. Because a lateral with both sides filled is not diagnostic due to superimposition.
646 - 6. The right lateral. (Your answer should have been one.)
646 - 7. To demonstrate: (1) those portions of the lung superimposed by the heart, and (2) the trachea and primary bronchi superimposed by the spine.

647 - 1. He should be instructed to cough gently. Harsh coughing can cause the contrast

material to go into the alveoli. Once there, it can only be eliminated by absorption.

647 - 2. Until the throat anesthesia has worn off because the material can be aspirated into the lungs rather than swallowed.

CHAPTER 4

648 - 1. Base - uppermost portion, in the midline. Apex - lower portion, to the left of the midline.
648 - 2. (1) Epicardium, outer layer; (2) myocardium, middle layer; and (3) endocardium, inner layer.
648 - 3. Pericardium.
648 - 4. Interventricular septum.
648 - 5. Horizontally.
648 - 6. Right ventricle.
648 - 7. Between the right atrium and the right ventricle.
648 - 8. Between the left atrium and the left ventricle.
648 - 9. Left atrium.
648 - 10. Left ventricle.
648 - 11. Right atrium.

649 - 1. Aorta.
649 - 2. Ascending.
649 - 3. Arch.
649 - 4. Diaphragm.
649 - 5. Coronary.
649 - 6. Innominate.
649 - 7. Left.
649 - 8. Left subclavian.
649 - 9. Right subclavian.
649 - 10. Internal carotid; external carotid.
649 - 11. Internal carotid.
649 - 12. Transverse processes.
649 - 13. Inferior cerebellar.
649 - 14. Basilar.
649 - 15. Circle of Willis.
649 - 16. Anterior cerebral; anterior communicating.
649 - 17. Posterior communicating; posterior cerebral.

650 - 1. Striothalmic, internal cerebral, and great cerebral vein of Galen.
650 - 2. Upper, mid, and basilar portions.
650 - 3. Dural sinuses.
650 - 4. Along the margins of the falx cerebri.
650 - 5. Internal jugular.
650 - 6. Deep.
650 - 7. No.
650 - 8. At the base of the skull.
650 - 9. Into the subclavian vein.
650 - 10. Vertebral vein.
650 - 11. Near the angle of the mandible.
650 - 12. Subclavian.
650 - 13. Innominate.
650 - 14 Superior vena cava.

651 - 1. By using moderate to high concentrations (iodine content) and a relatively high dose.
651 - 2. (1) The medium is of a higher concentration. (2) The medium is injected at a more rapid rate. (3) The medium is introduced directly into areas containing susceptible tissue.
651 - 3. Because of the dangers from direct introduction of the contrast medium, unlimited amounts cannot be introduced directly into certain areas. Consequently, the examination may have to be delayed or cancelled for the day if the radiographs are not adequate because the radiologist may have to allow a period of time to allow possible hemodynamic disturbances to subside.

652 - 1. b, c.
652 - 2. c.
652 - 3. a.
652 - 4. b.
652 - 5. b.
652 - 6. a.
652 - 7. a, c.
652 - 8. b, c.
652 - 9. a.
652 - 10. b.
652 - 11. c.

653 - 1. To facilitate entry into the remote site of injection and so that the catheter will maintain its position.
653 - 2. To reduce the expense involved, and to allow you to form catheters specifically for an anatomical condition for which a preformed commercial catheter is not available.

654 - 1. Those of the tubing manufacturer. Because different materials require different procedures and these techniques may become outdated quickly.

655 - 1. To facilitate passage of the catheter over the guide wire into the wall of the vessel.
655 - 2. The gloves should be powder free. They are worn to prevent the natural oils from your skin from adhering to the catheter.
655 - 3. Rotate a small section of the tubing near the end over a small flame or beaker of boiling water until it softens. Stretch the softened section until the desired degree of taper is achieved.
655 - 4. By placing it in cold water.
655 - 5. Depends upon your radiologist's desires—usually less than 2 cm.
655 - 6. Pass the tapered end over the guide wire.
655 - 7. The tapered end should fit snugly over the guide wire but it must be loose enough to allow passage of the catheter over the wire.
655 - 8. Stretch it with the guide wire in place.
655 - 9. By brushing with emory paper, as recommended by the manufacturer.

656 - 1. (1) Preshaped forming wire; (2) straight forming wire; and (3) guide wire.
656 - 2. 140° F.
656 - 3. Insert the stiff end—the end not introduced into the patient—into the catheter. Shape the wire and catheter as required. Soften the catheter over heat or in hot water. Cool in cold water. Remove the guide wire.
656 - 4. The catheter will not retain the proper shape.

657 - 1. To increase the delivery rate and reduce catheter whip.
657 - 2. (1) Remove each plug from the catheter—so it will not be introduced into the patient's blood stream. (2) Do not cut the

holes along a curved portion of the catheter—to prevent the guide wire from being passed through a side hole. (3) Do not cut the holes directly opposite one another or on the tapered tip—to prevent the catheter from being weakened.

658 - 1. To accommodate a connector which permits adaptation to a syringe or syringe tube *for injection.*

658 - 2. (1) Warm the flaring tool or soften the tip of the catheter. (2) Push the tip against the tip of the flaring tool. (3) Cool the flared end in cold water.

658 - 3. At the flared end—because of improper assembly of the connector.

659 - 1. Those of the manufacturer.
659 - 2. Gas.
659 - 3. 250° F.

660 - 1. a.
660 - 2. b.
660 - 3. a.
660 - 4. b.
660 - 5. a.
660 - 6. c.
660 - 7. b, c.

661 - 1. (1) Provides simultaneous fluoroscopic monitoring and filming; and (2) allows video tape recording of the injection, permitting immediate evaluation of the examination.

662 - 1. (1) Reduced dosage of contrast medium, and (2) more accurate interpretation.

662 - 2. (1) Film fog because of scatter radiation. Use crossed grids except for projections using an angled C.R.. Collimate the beams to the parts under study. Reduce the exposure from that normally used for single plane operation. (2) Loss of detail because of the large part-film distance on a lateral cerebral angiogram. Increase the FFD up to 72 inches.

663 - 1. You should become completely familiar with the operation of the injector by studying the manufacturer's instruction, before attempting to use it.

663 - 2. The contrast medium in the catheter overcomes the patient's normal skin resistance and can cause the patient to be electrocuted from a small amount of leakage current from the injector. Make sure all electrical appliances in the room are grounded to a common ground.

CHAPTER 5

664 - 1 First cervical.
664 - 2. Forty-two; forty-five; one.
664 - 3. Medullaris.
664 - 4. Ventral median; dorsal medial.
664 - 5. Spinal nerve.
664 - 6. Ventral nerve.
664 - 7. 31 pairs.
664 - 8. Cauca equina.
664 - 9. Gray matter; white matter.

665 - 1. Prone and lateral recumbent.

665 - 2. Both.

665 - 3. To straighten the lumbar lordosis which helps the radiologist to more accurately locate the injection site and perform a more accurate puncture.

665 - 4. To place the spine parallel with the table for the same reasons as indicated in the answer to exercise number 3 above.

665 - 5. The patient is lateral recumbent with his knees drawn up toward his chin and his shoulders drawn forward.

665 - 6. When there is an obstruction in the subarachnoid space.

665 - 7. Lateral recumbent.

665 - 8. The head is flexed and the head-end of the table is elevated.

665 - 9. To prevent the contrast medium from entering the ventricles of the brain.

666 - 1. The manometer is connected to the spinal fluid through a stopcock allowing the fluid to flow into the calibrated tube. The height of the fluid in the tubes indicates the pressure.

666 - 2. A means to indicate whether or not an obstruction is present in vertebral canal. The veins on one or both sides of the neck are compressed and released. If an obstruction is present, the intraspinal pressure is not affected. If an obstruction is not present, the pressure rises quickly during compression and drops quickly during release.

667 - 1. It may be necessary for a technician to maintain the patient's head in a hyperextended position. Also, the patient's head must not be allowed to drop below the level of the spine. This is to prevent the contrast medium from entering the ventricles and is usually accomplished only when the upper thoracic or cervical spinal canals are being demonstrated.

667 - 2. You must lock the vertical fluoroscopic adjustment in place or better still use a myelographic stop to prevent contact between the fluoroscopic unit and needle Throughout the examination keep the needle in mind so that it is not accidently touched. Do not perform AP or posterior oblique projections. If the needle is driven into the spinal nerves, permanent paralysis of a portion of the patient's lower anatomy could result.

668 - 1. Cerebrum.
668 - 2. Left; right; longitudinal fissure.
668 - 3. Gyri.
668 - 4. Frontal, parietal, temporal, occipital, and insula.
668 - 5. Gray matter.
668 - 6. Ventricles.
668 - 7. Laterals.
668 - 8. Lateral; third.
668 - 9. Suprapineal recess.
668 - 10. Aqueduct of Sylvius.
668 - 11. Foramen of Magendie.

669 - 1. Beneath the occipital lobe.

669 - 2. Vermis, and two hemispheres.
669 - 3. (1) Midbrain; (2) pons; and (3) medulla oblongata.
669 - 4. Cerebral peduncles.
669 - 5. Below the pons, above the foramen magnum.
669 - 6. Two bundles of fibers located on the anterior surface of the medulla oblongata.

670 - 1. Meninges.
670 - 2. Pia mater.
670 - 3. Spinal.
670 - 4. Second sacral.
670 - 5. Arachnoid.
670 - 6. Subarachnoid.
670 - 7. Cerebrospinal fluid.
670 - 8. Cisterns.
670 - 9. Cauda equina.
670 - 10. Dura mater.
670 - 11. Dural sinuses.
670 - 12. Subdural space.
670 - 13. Cisterna magna.

671 - 1. a.
671 - 2. b.
671 - 3. a.
671 - 4. a, b.
671 - 5. b.
671 - 6. a.
671 - 7. a.
671 - 8. b.
671 - 9. b.

672 - 1. Hypotension, headaches, restlessness, nausea, vomiting, and respiratory arrest.
672 - 2. AMBU, oxygen, suction apparatus, laryngoscope, blood pressure cuff, and intravenous fluids.
672 - 3. To minimize fluctuations in the blood pressure.
672 - 4. It is difficult to obtain the desired head positions without the cooperation of the patient.
672 - 5. (1) Explain the examination to him. (2) Stress the importance of the accuracy of the positions. (3) Show that you are visibly and actively concerned with his comfort and well being.
672 - 6. (1) The examination is uncomfortable for the patient. (2) Absorption of the contrast medium begins almost immediately.

673 - 1. A space occupying lesion may be obscurred, or simulated if one does not exist.
673 - 2. To allow the radiologist to evaluate the anatomy from right angle aspects without a change in the distribution of the contrast medium.
673 - 3. The ventricles are not completely filled with the contrast medium—consequently to visualize the entire ventricular system, the medium must be shifted throughout the system.
673 - 4. Perpendicular to the table.
673 - 5. Midway between the hairline and supraorbital ridge.
673 - 6. To a point superior to the superior border of the ear.
673 - 7. To prevent air (contrast medium) from escaping from critical ventricular locations.
673 - 8. One and one-half inches cranial to the external auditory meatus.
673 - 9. Patient supine, vertex of head on a support off the end of the table or on the table itself. Orbitomeatal line is horizontal.
673 - 10. Lateral with a horizontal C.R..
673 - 11. To demonstrate the third and fourth ventricles.
673 - 12. A point 1 inch anterior to, and 1 inch superior to, the external auditory meatus.
673 - 13. Median plane is parallel with, and the interpupillary line is perpendicular to, the film.
673 - 14. Using his forehead as a pivot point, he rocks his head gently through a 10° arc, as if shaking his head "no."

450

STOP– **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 OR NUMBER 2 PENCIL.**

90370 04 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

SPECIAL PROCEDURES

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

10-5

Multiple Choice

1. (600) Which of the following structures make up the roof of the mouth?

    a. Maxillae, palatine bones, and zygomatics.
    b. Lacrimals, palatine bones, and soft palate.
    c. Hard palate, soft palate, and nasal septum.
    d. Hard palate, soft palate, and maxillae and palatine bones.

2. (601) How many pairs of salivary glands are located about the oral cavity?

    a. 1.
    b. 2.
    c. 3.
    d. 4.

3. (601) Which of the following salivary ducts empties saliva from the parotid gland?

    a. Stenson's.
    b. Wharton's
    c. Duct of Rivinus.
    d. Duct of Bartholin.

4. (602) Which of the following structures serves as a passage for both food and air?

    a. Oropharynx.
    b. Nasopharynx.
    c. Laryngopharynx.
    d. Proximal esophagus.

5. (603) The sulcus intermedius is located on the

    a. medial margin of the C-loop.
    b. lesser curvature of the stomach.
    c. greater curvature of the stomach.
    d. inferior portion of the duodenal bulb.

6. (603) In what type of individual is the stomach located highest in the abdomen?

    a. Sthenic.
    b. Asthenic.
    c. Hyposthenic.
    d. Hypersthenic.

7. (604) The portion of the small bowel commonly referred to as the C-loop is the

    a. distal third of the jejunum.
    b. proximal half of the duodenum.
    c. proximal portion of the duodenal bulb.
    d. distal half of the duodenum and proximal jejunum.

8. (605) Which of the following portions of the large bowel are presented, in order, from the ileum to distal?

    a. Sigmoid colon, rectum, and anal canal.
    b. Rectum, sigmoid colon, and anal canal.
    c. Cecum, transverse colon, and hepatic flexure.
    d. Transverse colon, hepatic flexure, and descending colon.

9. (606) Which of the following structures prevents reflux into the common bile and pancreatic ducts?

    a. Duodenal papilla.
    b. Sphincter of Oddi.
    c. Sulcus intermedius.
    d. Pancreatic stop-valve.

10. (606) What is the name of the accessory duct which branches from the pancreatic duct and enters the duodenum?

    a. Duodenal duct.
    b. Duct of Santorini.
    c. Duct of Langerhans.
    d. Common hepatic duct.

11. (608) The brightness gain of an amplified image may be determined by

    a. adding minification gain to input gain.
    b. subtracting output loss from input gain.
    c. subtracting flux gain from phosphor gain.
    d. multiplying minification gain by flux gain.

12. (608) Flux gain in an image tube is realized by

    a. accelerating the electrons.
    b. accelerating the photons.
    c. focusing the electrons.
    d. focusing the photons.

13. (611) What is the major advantage of a dual field image tube?

    a. It provides a larger fluoroscopic field.
    b. The fluoroscopic image is slightly magnified.
    c. It reveals two fluoroscopic images simultaneously.
    d. The mode can be quickly changed to accommodate the examination.

14. (613) If the X-ray tube used with a single phase generator during cine recording continuosly produces radiation, which of the following conditions is likely to occur?

    a. Erratic frame speed.
    b. Uneven frame densities.
    c. Overexposed film strips.
    d. Underpenetrated film strips.

15. (613) What is the major advantage of synchronizing the X-ray exposure with the shutter during cine recording?

    a. Film contrast is improved.
    b. Film density is more even.
    c. The image is free from flicker.
    d. The patient receives less radiation.

16. (614) As a rule, cine film can resolve

    a. more line pairs than an image tube.
    b. fewer line pairs than an image tube.
    c. fewer line pairs than a cine camera.
    d. the same line pairs as an image tube.

17. (615) An advantage of television monitoring of the fluoroscopic image versus periscope viewing is that

    a. only one person at a time can view the image.
    b. the position of the viewer's head is not critical.
    c. the process is less expensive than is periscopic viewing.
    d. the videotape recordings of the television process excels the quality of an image tube.

18. (615) A major drawback of television as compared to image tube fluoroscopy is the

    a. lack of replay.
    b. expense involved.
    c. criticality of the patient's head position.
    d. need for monitors outside the fluoroscopic room.

19. (616) If the patient is improperly prepared for a contrast examination of the digestive system, the presence of food, liquids, gas, or fecal material would more likely cause which one of the following results?

    a. Excessive part contrast.
    b. Revision of instructions.
    c. Difficult interpretations.
    d. Improper use of the contrast medium.

20. (617) Barium sulfate paste or cream preparations are used as a contrast medium for examination of the pharynx and esophagus because of their characteristic of

    a. adhering to mucosa.
    b. adhering to the bone.
    c. neutralizing acidity.
    d. settling out of suspension.

21. (617) If you were to allow micronized and ionized barium sulfate powders to contact metal while mixing, a likely result would be

    a. prolongation of the mixture's useful life.
    b. prevention of the settling-out property.
    c. lengthening the time of suspension.
    d. a loss of the suspension property.

22. (618) A small probe is used in sialography for the purpose of

    a. locating and exploring the mouth's main ducts.
    b. anesthetizing the area around the duct's openings.
    c. injecting contrast material into the main ducts of the mouth.
    d. stimulating the glands so that the duct location is made easier.

23. (618) The radiologist instructs a patient that has been subjected to a sialogram to continue the use of lemon juice for from one to three days for the purpose of

    a. locating main glands.
    b. evacuating the contrast material.
    c. overcoming the effects of fatigue.
    d. removing an obstruction in a minor duct.

24. (619) Examinations of the pharynx using barium sulfate are best if the exposure is made at the instant that the

    a. patient has been instructed to swallow.
    b. patient begins to drink barium through a straw.
    c. patient's Adams's apple begins to move anteriorly.
    d. patient's Adam's apple reaches its most anterosuperior position.

25. (619) While making the four projections of the chest for the heart series with the esophagus outlined with barium paste, what relationship is established for the PA exposure as compared to a normal PA chest exposure?

    a. Remains the same.
    b. Decreased slightly.
    c. Increased slightly.
    d. Must be greatly decreased.

26. (620) Resuscitation equipment should be readily available during hypotonic duodenography to administer artificial respiration in case

    a. control of the voluntary muscles is lost.
    b. patient faints because of hyperoxygenation.
    c. mucosa of the duodenum becomes oversaturated.
    d. the contrast medium does not pass into the duodenum causing obstructive anoxia.

27. (620) An erect PA projection accomplished during an upper GT series would specifically reveal the

    a. profile view of the pylorus and the duodenal.
    b. stomach's relative position, and its true size and shape.
    c. relationship between the stomach and the retrogastric structures.
    d. air-contrast view of the stomach's body, the pylorus, and the duodenal bulb.

28. (621) What method of contrast examination employs a substitute for the water with which the barium powder is mixed, thereby hastening stomach evacuation and motility?

    a. Intubation.
    b. Retrograde.
    c. Frequent interval.
    d. Cold isotonic saline.

29. (621) What method of contrast examination of the small bowel is used to detect organic filling defects by introduction of a barium enema?

    a. Intubation.
    b. Retrograde.
    c. Frequent interval.
    d. Cold isotonic saline.

30. (622) The pneumocolon is used in direct air-contrast studies of the colon to introduce both air and barium. What is the position of its triangular support to introduce barium?

    a. Any side down.
    b. Long side down.
    c. Both short sides down.
    d. Either short side down.

31. (623) A correct step in the preparation of the barium liquid for colon examination is to

    a. never mix before use.
    b. pour water into the barium powder.
    c. prevent air-lock by bleeding the tube.
    d. use a hydrometer to spot check the thickness of the barium preparation.

32. (624) To recoat the walls of a patient's colon while performing air-contrast radiographs, before performing each radiograph, you should

    a. rotate him 360°.
    b. rotate him 180°.
    c. have him turn over.
    d. have him hold his ankles.

33. (624) Because of the radiolucency of the air, the relative exposure that should be used for air-contrast projections of the colon is

    a. normal.
    b. less than normal.
    c. more than normal.
    d. varied, dependent on other factors.

34. (625) The gallbladder in a hypersthenic individual is usually located

    a. superimposed over the spine.
    b. low in the abdomen near the spine.
    c. at the level of the right eighth rib.
    d. high in the abdomen near the lateral wall.

35. (625) If routine projections reveal overlying gas over the gallbladder, one way to alleviate the situation is to make PA or oblique projections with the patient in the

a. erect position.
b. recumbent position.
c. Trendelenburg position.
d. same original position after a "fatty meal" has been given him.

36. (626) Which of the following methods of cholangiography fits all of the following: Is performed during a cholecystectomy, usually after the gallbladder is removed, and the contrast media is injected directly into the biliary ducts?

a. T-tube.
b. Operative.
c. Intravenous.
d. Transhepatic.

37. (628) Both ureters are collectively about how long?

a. 9 to 10 feet.
b. 56 to 68 cm.
c. 28 to 34 inches.
d. 28 to 34 cm.

38. (629) Which is the only statement below that refers to a normal, moderately full bladder?

a. Contains approximately 500 cc of urine.
b. Its ureteral-orifice openings are about 2.5 cm apart.
c. Its relative location is the same as it was when empty.
d. Its muscular arrangement keeps its size constant, whether full or empty.

39. (630) Filtration of contrast material or of blood into the surrounding tissues at or near the injection site is referred to as what type of reaction?

a. Hematoma.
b. Technique.
c. Hemodynamic.
d. Anaphylactic.

40. (630) After injection of a contrast material, a patient's reactions include: urticaria, accompanied by itching; wheezing; and by watery eyes. It is more likely that this reaction is caused by

a. allergy to the contrast material.
b. infiltration of contrast material.
c. movement involving blood circulation.
d. any one, or all, of the above causes.

41. (631) All statements that follow concern the importance of establishing and maintaining an emergency tray. Which statement is of prime importance?

a. A checklist is essential.
b. The cart must be on rollers.
c. Necessary items must be available when and where needed.
d. All equipment must be assembled on one cart and inventoried.

42. (633) A manufacturer recommends a contrast medium dosage for its product of 0.5 cc per kilogram of body weight. If your radiologist asks you to follow that recommendation and prepare a dose for a 9-year old child weighing 60 lbs., what is the correct dosage?

a. 7.5 cc.
b. 13.6 cc.
c. 30.0 cc.
d. 66.5 cc.

43. (634) Before injection of contrast medium for an IVP, perform a scout film for all of the following except to

a. decrease radiation danger.
b. determine if patient is radiologically "clean."
c. make necessary preadjustments concerning exposure and positioning.
d. discover abnormalities that might later become obscured by the contrast media.

44. (635) Under what circumstances would a patient be provided with a gauze-covered container as a part of the postvoiding projection?

a. In case a urinary stone is suspected.
b. To evaluate the mobility of the kidneys.
c. To increase the amount of pressure on the ureters.
d. To check for gravitational emptying of the renal calyces.

45. (635) In the performance of IVP radiographs, how can the purpose of compression be partially satisfied for those patients who cannot tolerate compression of the ureters?

a. Substitute a foam-rubber pad.
b. Substitute a blood-pressure cuff.
c. Use the Trendelenburg position—10° to 20°.
d. Do not angle the tube caudally to the table tilt.

46. (636) How much carbonated water would normally be given to an 8-year child as a part of an IVP if you desire to provide better demonstration?

a. 2 ounces.
b. 2 grams.
c. 12 grams.
d. 12 ounces.

47. (637) At what time intervals should contrast material be injected into the vascular system and radiographs made to determine whether or not hypertension is caused by stenosis of a ranal artery?

a. One time only.
b. One minute intervals for 10 minutes.
c. One-half of 1 minute intervals for about 5 minutes.
d. The interval is not important—but a time duration of 5 minutes is.

48. (638) In the performance of cystography and chain cystourethrography, good procedure dictates that the

a. contrast medium must always be negative.
b. voiding films of the urethra are usually performed under fluoroscopy.
c. CR should, in all cases, be angled 15° to 20° caudally for an AP cystogram.
d. radiographs of the bladder should be centered to the level of the greater trochanger.

49. (639) The curved superior portion of the uterus is the

a. cervix.
b. fundus.
c. ovaries.
d. oviducts.

50. (639) Normal fallopian tubes extend laterally from the uterus to the ovaries and are about how long?

a. 8 mm.
b. 12 cm.
c. 2 to 4 cm.
d. 1 foot.

51. (640) Hysterosalpingography and a Rubin's test are both performed to determine patency of the

a. cervix.
b. vagina.
c. bladder,
d. fallopian tubes.

52. (640) When possible, two technicians should perform radiographs that require contrast material to be injected into the uterus and fallopian tubes to

a. lessen the patient's discomfort.
b. provide more accurate radiographs.
c. assist the examiner with the injection.
d. reduce the scatter exposure to one technician.

53. (641) The larynx is suspended from the

a. trachea.
b. hyoid bone.
c. laryngeal pharynx.
d. fourth cervical vertebra.

54. (642) Another name for that part of the bronchial tree called the secondary bronchi is

a. lobar bronchi.
b. tertiary bronchi.
c. segmental bronchi.
d. bronchioles, alveoli, or atria.

55. (642) In what structure of the bronchial tree does the exchange of gases through diffusion occur?

a. Atria.
b. Alveoli.
c. Bronchioles.
d. Tertiary bronchi.

56. (643) The area between the lungs that separates them from each other is called the

a. fissure.
b. lung base.
c. mediastinum.
d. diaphragmatic surface.

57. (644) Which is the most commonly used method of introducing contrast medium into the lungs and offers selective visualization of a desired portion of the bronchial tree?

a. Cricothyroid.
b. Supraglottic only.
c. Intratracheal intubation.
d. Supraglottic and intraglottic.

58. (644) What method of introducing contrast media as a part of a bronchogram employs a needle inserted directly into the trachea as a part of the process?

a. Intraglottic.
b. Cricothyroid.
c. Supraglottic.
d. Intratracheal intubation.

59. (645) What end result may result from peripheral flood if the patient coughs excessively during a bronchogram?

a. Vomitus.
b. Cephalalgia.
c. Loss of contrast media.
d. Difficulty in interpretation.

60. (645) As a part of a patient's briefing in regard to coughing during a bronchogram, what preventive measure should he take if he feels an urge to cough?

a. Pant (take rapid, shallow, breaths).
b. Perform the Val Salva maneuver.
c. Take long, deep breaths.
d. Ignore the urge.

61. (647) For what period of time should food and liquids be withheld from a patient who has received a bronchogram and why?

a. 4 hours to prevent aspiration into the lungs.
b. 8 hours to prevent dilution of the contrast medium.
c. Until the patient coughs up the medium to prevent floculation.
d. Until the anesthesia has worn off to prevent aspiration into the lungs.

62. (648) The viscosity of blood is approximately how many times that of water?

a. 1/3.
b. 3.
c. 5.
d. 10.

63. (648) The broad base of the heart is uppermost and, in respect to the midline, is located in the

a. center.
b. to the right.
c. well to the left.
d. well to the right.

64. (649) What arteries are the first two branches off the aortic arch and serve to supply the heart muscle with blood?

a. Carotid.
b. Coronary.
c. Pulmonary.
d. Subclavian.

65. (649) At the base of the brain, the carotid and vertebral systems join and form a juncture commonly known as

a. Robinson's circle.
b. the circle of Weber.
c. the circle of Willis.
d. the circle of Haller.

66. (650) The part of the venous network of the head and neck that empties the upper, mid, and basilar surfaces of the hemispheres includes the anastomatic

a. veins of Trolard and Labbe.
b. veins of Willis and Galen.
c. external and internal jugulars.
d. cerebellar veins.

67. (650) The larger vein that results from the union of the bilateral innominate veins is the

a. subclavian.
b. internal jugular.
c. superior vena cava.
d. inferior vena cava.

68. (651) Besides the use of highly concentrated media, the dilution of the contrast medium can be prevented in diagnostic angiograms by injecting

a. no iodine.
b. a high dose.
c. less iodine.
d. a low-iodine dose over a prolonged period of time.

69. (651) One reason that contrast media, administered during angiography, increases the chance of a serious reaction is that it normally is injected

a. without iodine.
b. at a slow rate.
c. at a rapid rate.
d. in relatively low concentrations.

70. (652) Which of the three methods (if any) for introducing angiographic contrast media employs all the following techniques at times: Uses a catheter; automatic injection is more often used; catheter may be sutured in position; injection may be by hand or by automatic injection; includes a surgical countdown?

a. None of the three.
b. Percutaneous injection.
c. Selective catheterization.
d. Percutaneous-selective catheterization.

71. (652) Which of the three methods for introducing angiographic contrast media employs all the following techniques at times: Uses a catheter; catheter is passed over a guide wire; a needle is introduced into a blood vessel; injection may be by hand or by automatic injection; guide wire is removed from within the catheter?

a. All three methods.
b. Percutaneous injection.
c. Selective catheterization.
d. Percutaneous-selective catheterization.

72. (653) The soundest reason for a radiology department forming an angiographic catheter locally would be because of

a. normal anatomical variations.
b. facilitating entry into remote sites of injection.
c. necessity for maintaining the catheter's position of injection.
d. nonavailability of a suitable commercial catheter at an economical price.

73. (654) What procedures should be followed when forming angiographic catheters and why?

a. Those used to form nylon catheters because nylon is the only material used.
b. Those of the manufacturer because preformed catheters are correctly shaped.
c. Those of the manufacturer because the procedures have a tendency to become outdated quickly.
d. Those used to form polyethylene catheters because nylon responds to heat the same as polyethylene.

74. (655) The tip of an angiographic polyethylene catheter must be correctly tapered so that the catheter can be inserted into a vessel

a. remotely.
b. with softened end.
c. snugly over a guide wire.
d. and maintain its position after entry.

75. (655) How long should the "tapered" section of an angiographic polyethylene catheter be after it is cut?

a. 2 cm.
b. 2 inches.
c. Usually less than 2 cm.
d. Less than 2 cm in all cases.

76. (656) In forming the end section of a polyethylene catheter, if you do not soften the catheter sufficiently, the catheter will

a. remain shaped as the wire.
b. not retain the shape of the wire.
c. whip from a recoil effect.
d. increase its normal delivery rate.

77. (658) The end of a catheter is flared so that it will

a. penetrate easier.
b. sterilize properly.
c. retain its shape properly.
d. permit connection of a syringe (or syringe tube) for injection.

78. (659) The best method of sterilizing polyethylene angiographic catheters is to

a. autoclave them.
b. use a chemical-immersion method.
c. autoclave them with 200° F. or lower temperatures.
d. use only gas sterilization, followed by a delay of a few days.

79. (660) Which type of film changer, if any, has a high-filming rate with but little film waste?

a. No type listed below satisfies both requirements.
b. The roll film changer.
c. The cut film changer.
d. The cassette changer.

80. (662) The most significant advantage of biplane studies resulting from biplane film changer operation is that

a. the patient receives less dosage.
b. the lack of scatter radiation causes film fog.
c. the radiologist can more accurately study the structures.
d. only one X-ray tube is used, thereby lowering operating costs.

81. (662) A problem sometimes encountered with a lateral biplane cerebral angiogram is the

a. increase in exposure necessary.
b. right angle studies are made simultaneously.
c. reduction in patient dosage reduces scatter.
d. loss of detail due to the large part film distance.

82. (663) The greatest hazard when using an automatic injector is

a. electrocution of patient.
b. sanitation involved in injection.
c. operational instructions unknown.
d. great pressures developed during injection.

83. (664) What two structures divide the spinal cord into lateral halves?

a. Ventral lateral sulcus and nerve root.
b. Ventral lateral sulcus and spinal nerve.
c. Ventral median fissure and dorsal medial sulcus.
d. Ventral median fissure and dorsal lateral sulcus.

84. (664) Thirty-one pairs of spinal nerves exit from the spinal sections in what directions?

a. Cervical and thoracic—transversely; lumbar and sacral—vertically.
b. Cervical—vertically; thoracic and lumbar—transversely.
c. Cervical, thoracic, and lumbar—vertically; sacral transversely.
d. Cervical thoracic and lumbar—transversely; sacral and coccygeal—vertically.

85. (665) Contrast material is being introduced into the subarachnoid space using a spinal puncture with the patient prone. A rolled pillow or similar object is placed under the patient's lower abdomen because it

a. straightens the lumbar lordosis.
b. makes the patient more comfortable.
c. reduces the spaces between the spinous processes.
d. allows the medium to gravitate to the presacral area.

86. (665) What action should be taken to prevent the contrast material from entering the ventricular system of the brain during a cisternal puncture?

a. Elevate the foot end of the table 15°.
b. Immediately after injection, hyperflex the head.
c. Immediately after injection, hyperextend the head.
d. Maintain hyperextension of the head during and after the injection.

87. (666) The radiologist will ask to compress the patient's blood vessels along the side of the patient's neck during a lumbar puncture to

a. locate the cisterna magna.
b. test for the normal circulation time.
c. test for an obstruction in the vertebral canal.
d. measure the exact amount of cerebrospinal fluid.

88. (667) Why should you insure that the vertical adjustment of the fluoroscopic unit is locked in place during the fluoroscopic phase of a myelogram performed by lumbar puncture?

a. Short FFD results in increased magnification with a subsequent loss of detail.
b. Gravitation of the medium may result in increased intraspinal pressure.
c. Infection of the puncture site could occur if contact is made with the unit.
d. Accidental lowering of the unit could result in permanent paralysis of the patient's lower anatomy.

89. (667) Which of the following post-fluoro projections should not be made during a myelogram performed with a lumbar puncture?

a. Standard laterals.
b. Cross-table laterals.
c. AP and posterior obliques.
d. PA and anterior obliques.

90. (668) What structure divides the cerebrum into two hemispheres?

a. Gyrus.
b. Major sulcus.
c. Transverse fissure.
d. Longitudinal fissure.

91. (668) What structure(s) secrete cerebrospinal fluid?

a. Ventricles.
b. Spinal canal.
c. Hypothalamus.
d. Corpus callosum.

92. (669) What three structures comprise the brain stem?

    a. Medulla oblongata, pons, and vermis.
    b. Midbrain, pons, and medulla oblongata.
    c. Midbrain, cerebrum, and spinal canal.
    d. Cerebellum, cerebrum, and occipital lobe.

93. (669) What portions of the midbrain carry impulses between the cerebrum and spinal cord?

    a. Meninges.
    b. Central stalks.
    c. Cerebral pyramids.
    d. Cerebral peduncles.

94. (670) Which of the following statements best describes the pia mater?

    a. It contains a periosteal layer.
    b. It is the outermost meningeal layer.
    c. It closely covers the brain and spinal cord.
    d. It lies between the arachnoid membrane and the dura mater.

95. (670) What are the wide deep regions of the subarachnoid space called?

    a. Cisterns.
    b. Dura cavities.
    c. Dural sinuses.
    d. Subarachnoid cavities.

96. (671) Pneumoencephalography and ventriculography are similar examinations in that

    a. they are performed to examine the ventricles.
    b. the contrast medium is introduced through trephine openings.
    c. the first radiographs are made with the patient upright.
    d. the contrast medium is introduced by lumbar or cisternal puncture.

97. (672) The patient's legs should be wrapped with elastic bandages during intracranial pneumography to

    a. prevent injuries.
    b. reduce the intraspinal pressure.
    c. immobilize him for the radiographs.
    d. minimize fluctuations in the blood pressure.

98. (672) Why should intracranial pneumographic radiographs be performed quickly?

    a. The protruding needle is a potential hazard.
    b. The contrast medium disappears within 10 minutes.
    c. Evaporation of spinal fluid decreases contrast.
    d. Absorption of the contrast medium begins almost immediately.

99. (673) Why should two or more intracranial pneumographic projections be made without moving the patient's head?

    a. To evaluate the anatomy from two angles without changing the distribution of the medium.
    b. To prevent discomfort to the patient since head movement causes him some pain.
    c. To allow the contrast medium to completely fill the ventricle under examination.
    d. To determine whether or not vertical absorption is present.

100. (673) An autotomogram should be performed during intracranial pneumography to visualize the

    a. lateral ventricles.
    b. foramina of Monro.
    c. foramen of Magendie.
    d. third and fourth ventricles.

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CDC 90370

RADIOLOGY TECHNICIAN

(AFSC 90370)

Volume 5

General Information and Administration

Extension Course Institute
Air University

10-5

Preface

IF WE WERE to attempt to briefly describe a radiology technician, we could possibly say that he has the technical, administrative, and supervisory know-how to efficiently run a radiology department. The first four volumes of this CDC have mostly been orientated toward the technical aspects. The first three chapters of this volume conclude our technical discussions. They include: (1) the muscular, integumentary, and endocrine systems; (2) field radiography, and (3) radiation therapy. Chapter 4 provides you with a look at the radiology career field. Chapter 5 deals with administration and supervision. It is generally an accepted fact that administration and supervision cannot be fully learned from a text. The text must be complemented with the necessary on-the-job experiences. Therefore, we will attempt to provide you with enough basic information so that together with your OJT and experiences, you may smoothly make the transition from a 5-level specialist to a 7-level technician.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to the School of Health Care Sciences/MST, Sheppard AFB TX 76311.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guide, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of January 1975.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Muscular, Integumentary, and Endocrine Systems

IN VOLUMES 2 and 4 of this CDC we discussed the anatomy and physiology of the skeletal system and the five basic body systems related to special procedures. This chapter concludes our study of anatomy and physiology. It includes three sections covering the muscular, the integumentary, and the endocrine systems. No study of anatomy and physiology is complete without a look at these three systems. As you will see, they are as vital to life as any of the major organs previously studied. We begin with the muscular system.

1-1. Muscular System

Most physiological activities of the body can be related to movement produced by the muscles. Generally, we can exercise voluntary control over some movements, such as the act of walking, while other movements, such as the heartbeat, are precipitated by conditions not under our voluntary control. Our discussion of the muscular system includes a look at the three types of muscular tissue, some skeletal muscle characteristics, and finally a study of some specific skeletal muscles.

800. Given the three types of muscular tissue, identify each in terms of location, function, or appearance of the tissue.

Types of Muscular Tissues. All of the muscles found in the human body can be classified into one of three types: (1) *skeletal,* (2) *smooth,* or (3) *cardiac.*

Skeletal. By far, most of the muscles in the body are classified as *skeletal.* In fact, they alone constitute about 40 percent of the body weight. Skeletal muscles are so designated because they are attached to bones. They are also sometimes referred to as voluntary muscles because we exercise conscious control over them. As suggested in the introduction to this section, the act of walking results from voluntary control over our muscles. In this case, we regulate the movements of our legs by consciously and voluntarily influencing the actions of certain leg muscles. Skeletal muscles are also sometimes called striated muscles due to their microscopic appearance. When magnified, a skeletal muscle fiber appears to be composed of alternate light and dark parallel stripes.

Smooth. The second type of muscle tissue is classified as *smooth.* This type of tissue is composed of spindle-shaped fibers which do not appear to have striations or stripes when examined microscopically. Smooth muscles are sometimes termed visceral muscles because they are located primarily in the walls of various body organs, such as the stomach and the bowel. These muscles are stimulated by impulses from the autonomic nervous system, which, in case of the structures mentioned, conduct the peristaltic action. The walls of blood vessels also contain smooth muscle fibers which account for the dilatation and constriction of the vessels. Since smooth muscles are stimulated by self-controlling impulses, they are sometimes called involuntary muscles.

Cardiac. Cardiac muscle tissue, as the name implies, makes up only the walls of the heart. Heart muscles microscopically appear similar to the skeletal muscles in that they are striated. Their actions—contraction and

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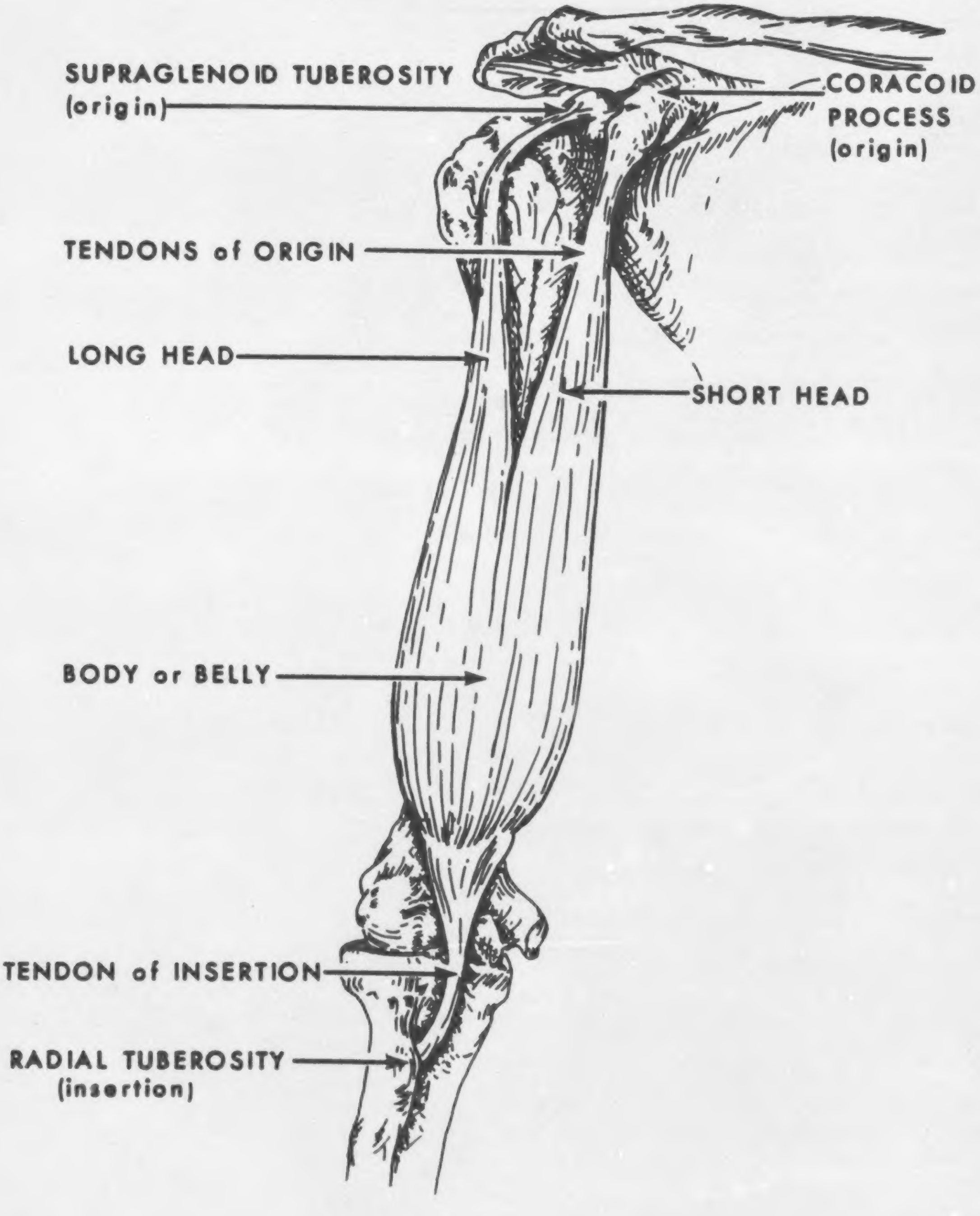

Figure 1-1. The major parts of a typical skeletal muscle—the biceps brachii.

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relaxation—are responsible for the "pumping" action of the heart which circulates blood throughout the body. Naturally, cardiac muscle fibers are involuntarily controlled.

Exercises (800):

Match the type of muscle tissue in column B with the appropriate statement or word in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, more than one column B item may match a single column A entry.

Column A

____1. Responsible for pumping blood to the lungs.
____2. Cannot be consciously activated.
____3. Microscopically appears striated.
____4. Voluntarily controlled.
____5. Visceral.
____6. Peristalsis.
____7. Responsible for arm movement.
____8. Comprises the heart muscle.
____9. Attaches to the humerus.
___10. Comprises almost half of the body weight.

Column B

a. Skeletal.
b. Smooth.
c. Cardiac.

801. Identify by name, location, and attachment the parts of skeletal muscles in general and the biceps brachii in particular.

Parts of Skeletal Muscles. Skeletal muscles are composed of three basic parts: (1) the *body*, (2) the *origin*, and (3) the *insertion*. (See fig. 1-1.) The *body* or *belly* is the large middle portion of the muscle. The *origin* is the proximal point of attachment, located on the relatively more fixed anatomical structure. The *insertion* is the distal point of attachment, located on the more movable structure. The biceps brachii, illustrated in figure 1-1, among other functions flexes the elbow. The distal portion of that muscle is attached to the forearm which is more movable during elbow flexion than the proximal structure of origin—in this case the scapula. Notice that the biceps brachii has two points of origin, since the proximal portion is split into two divisions. When such is the case, each division is sometimes referred to as a *head*. Also, notice that the muscle tissue itself terminates in a tendon which connects the muscle to the points of origin and insertion. NOTE: In actuality, the origin and insertion of a skeletal muscle is functionally interchangeable. For example, if you chin yourself on a horizontal bar, the act includes flexion of the elbows, but your forearms are relatively stationary while the remainder of your body moves. This situation would reverse the origin and insertion of the biceps brachii. For general descriptive purposes, however, the origin is the proximal portion and the insertion is the distal portion.

Exercises (801):

1. What are the names of the three basic parts of a skeletal muscle?

2. What is the origin of a skeletal muscle? The insertion?

3. Where, specifically, is the origin of the biceps brachii?

4. If a skeletal muscle is divided into two or more proximal portions, what are the portions called?

802. Identify actions of the skeletal muscles in general and certain arm muscles in particular.

Skeletal Muscle Actions. The human body has more than 400 skeletal muscles; they function in groups to provide varying degrees of movements. Groups arranged so that they oppose each other are called *antagonistic* muscle groups. Their antagonistic actions are accomplished, for example, by flexors in opposition to extensors. An example of such action is the flexion and extension of the elbow. As the biceps brachii contracts, the triceps brachii relaxes and flexion of the elbow occurs; reversely, as the triceps brachii contracts, the biceps brachii relaxes and extension of the elbow occurs. During elbow flexion the triceps brachii is the antagonist of the biceps brachii. These combined actions of antagonistic muscles provide smooth, coordinated movements and help to regulate and stop the movements.

In most instances more than one muscle crosses and regulates the movement of a particular joint. However, certain muscles are primarily responsible for the movement and are called *prime movers.* A single muscle or group of muscles may be primarily responsible for the movement. In case of flexion of the elbow, the biceps brachii, the brachialis, and the brachioradialis all contribute to the movement. The biceps brachii and the brachialis are primarily responsible for the movement while the brachioradialis is considered an *agonist.* An agonistic muscle, then, is one which aids a prime mover. We can also say that an antagonistic muscle is one which opposes a prime mover.

In addition to prime movers, agonists and antagonists, there are also *synergistic* muscles. These muscles stabilize joints so that the prime mover and the agonist function efficiently. Referring once again to elbow flexion, as the appropriate muscles act to flex the joint, certain muscles about the shoulder must contract to stabilize the arm so that flexion occurs in the desired direction or plane. Such stabilizing muscles are said to be synergistic.

Exercises (802):

Indicate whether the following statements are true or false. If you indicate "false," explain your answer.

T F 1. A group of muscles that flexes or extends a particular part is called an agonistic muscle group.

T F 2. Although antagonistic muscles work against each other, their combined efforts effect desirable muscle movements.

T F 3. A particular muscle may be classified as both an antagonist and a prime mover.

T F 4. An agonistic muscle is a prime mover.

T F 5. Prime movers and agonistic muscles may provide identical movements.

T F 6. The brachioradialis muscle is considered a prime mover.

T F 7. Synergistic muscles are those that stabilize a part during movement.

803. Given a list of eight skeletal muscles, identify each by origin, insertion, or action.

Origin, Insertion, and Action of Specific Skeletal Muscles. At this point we will conclude our discussion of the muscular system with a close look at some of the skeletal muscles. We will examine eight such muscles in terms of their origin, insertion, and action.

Serratus anterior. The *serratus anterior* is a thin muscle situated between the ribs and the scapula. It originates on the lateral aspects of the first eight ribs and inserts into the vertebral border of the scapula. Its major function is to rotate the scapula.

Trapezius. The *trapezius* is the large posterior muscle of the neck and shoulder. Anatomically, it is broken down into the upper middle and lower portions. The origins of the trapezius extend from the external occipital protuberance down the nuchal ligament and along the spinous processes of the thoracic vertebrae. The insertions include the lateral one-third of the clavicle, the vertebral border of the scapula, and the base of the scapula spine. Actions of the trapezius include rotation and adduction of the scapula. It also draws the scapula cranially or downward.

Deltoid. The *deltoid* is the large fan-shaped muscle on the apex of the shoulder. It originates from the lateral portion of the clavicle, the acromion process of the scapula, and the spine of the scapula. The deltoid muscle inserts into the deltoid tuberosity, located approximately in the middle of the

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shaft of the humerus. Actions of the deltoid are flexion, extension, and abduction of the arm.

Pectoralis major. The *pectoralis major* (commonly called the breast muscle) originates from the medial portion of the clavicle and the first six costal cartilages. It inserts into the edge of the bicipital groove of the humerus and contributes to adduction, medial rotation, and extension of the arm.

Psoas major. The *psoas major* muscle, often seen on abdominal radiographs, originates from the transverse processes and bodies of the lumbar vertebrae and inserts into the lesser trochanter of the femur. It flexes the thigh, flexes the lumbar vertebral column and bends it laterally.

Quadriceps femoris. The *quadriceps femoris* are considered to be the largest and most powerful group of muscles in the body. Located on the anterior thigh, the muscle group originates from the anterior superior iliac spine, and from the lateral surface, the lower medial surface, and the upper two-thirds of the anterolateral surfaces of the femur. They insert into the tibial tuberosity. The actions of the quadriceps femoris include thigh flexion, and knee extension.

Gastrocnemius. The *gastrocnemius* is located on the posterior portion of the lower leg and originates from the posterior portion of each femoral condyle. It inserts into the posterior surface of the calcaneus by way of the Achilles tendon. Actions include plantar flexion of the foot, extension of the knee joint, and flexion of the knee joint.

Exercises (803):

Match the skeletal muscles in column B with the appropriate insertion, origin, or action in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once, more than once, or not at all. In addition, more than one column B item may match a single column A entry.

Column A

Origin

____1. Femoral condyles.
____2. First six costal cartilages.
____3. Clavicle.
____4. Lumbar vertebrae.
____5. Thoracic vertebrae.
____6. Anterior superior iliac spine.

Insertion

____7. Midportion of humerus.
____8. Proximal portion of humerus.

Column B

a. Serratus anterior.
b. Trapezius.
c. Deltoid.
d. Pectoralis major.
e. Psoas major.
f. Quadriceps femoris.
g. Gastrocnemius.

Column A

Insertion

____9. Posterior calcaneus.
____10. Tibial tuberosity.
____11. Lesser trochanter.

Action

____12. Plantar flexion of foot.
____13. Knee extension.
____14. Thigh flexion.
____15. Rotation of the scapula.
____16. Flexion or extension of arm.

1-2. Integumentary System

The integumentary system, or skin, not only covers most visible parts of the body, but is associated with several body functions. It protects the deeper tissues from injury and dehydration, and (unless the skin is broken) it prevents the entrance of bacteria-producing microorganisms. The skin, along with some of its appendages, helps to regulate body temperature through the dilatation and constriction of its blood vessels. Another important function is the elimination of certain waste products. In this section we will discuss the structure of the skin as well as its appendages.

804. Given a list of the layers of the skin, identify each in terms of location, function, name, or characteristic.

Structure of the Skin. The skin is composed of two principal layers: the outer layer or *epidermis*, and the inner layer or *dermis*. Each principal layer is subdivided into structural sublayers.

The epidermis. The epidermis contains no blood vessels or lymph vessels and consists of five structural sublayers. From external to internal they are: (1) *stratum corneum*, (2) *stratum lacidum*, (3) *stratum granulosum*, (4) *stratum spinosum*, and (5) *stratum basale.*

The external layer of the epidermis, or stratum corneum, varies in thickness, depending upon the amount of trauma to which it is subjected. Accordingly, it is thickest over the palms and soles and thinnest over well-protected areas of the body. The stratum corneum is composed of cells which are continuously dying and sloughing off.

The second layer of the epidermis is called the stratum lucidum, so named because of its clearness or translucence. This layer acts as a medium for new cells passing to the stratum corneum.

The third or middle layer of the epidermis, or stratum granulosum, consists of two or three rows of flattened cells.

The stratum spinosum, or fourth layer of the epidermis, is composed of several layers of polygonal cells.

The deepest layer of the epidermis is called the stratum basale. It is sometimes called the stratum cylindricum because its cells are cylindrically shaped. This layer is responsible for the growth of the epidermis, since it is the only epidermal layer that reproduces new cells. As the new cells are formed, they gradually pass to the stratum corneum where, after dying, they eventually slough off the external surface. Skin pigmentation is determined by the amount and activity of melanin found in this layer.

The dermis. The dermis is composed of two structural sublayers: (1) the *papillary* layer and (2) the *reticular* layer. The papillary layer is located directly beneath the deepest layer of the epidermis. It derives its name from the many nipple-like projections which are located on the outer surface. The outer surface of the reticular layer joins the inner surface of the papillary layer and extends to the subcutaneous tissue.

Exercises (804):

Match the skin layer in column B with the appropriate statement or phrase in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, more than one column B item may match a single column A entry.

Column A

____1. Deepest epidermal layer.
____2. Deepest dermal layer.
____3. Joins subcutaneous tissue.
____4. Responsible for skin color.
____5. Its cells continuously slough off.
____6. Middle epidermal layer.
____7. Located between stratum basale and reticular layer.
____8. Produces new epidermal cells.
____9. Epidermal layers.
____10. Dermal layers.
____11. Thickness depends upon exposure to trauma.
____12. Contains melanin.

Column B

a. Stratum corneum.
b. Stratum granulosum.
c. Stratum basale.
d. Papillary layer.
e. Stratum lucidum.
f. Reticular layer.
g. Stratum spinosum.

805. Indicate the structure, location, and functions of the nails, hairs, sweat glands, or sebaceous glands.

Appendages of the Skin. The appendages of the skin are the *nails, hairs, sweat glands,* and *sebaceous* glands.

Nails. The nails are flat, hard structures which contain a root, the proximal portion of which is hidden by the skin; and a body, which is visible. The external surface of the nail proper consists of the stratum lucidum, which is greatly thickened. The deeper (internal) surface of the nail consists of the deepest layer of the epidermis.

Hairs. A hair consists of a root, which is below the surface of the skin, and a shaft which is visible above the skin. The root is situated inside the follicle, which is an indentation of the epidermis extending into the subcutaneous layer of tissue. (See fig. 1-2.) Minute muscles called arrector muscles originate from the dermis and insert into the hair follicle. They insert onto the side of the follicle toward which the shaft slopes, as seen in figure 1-2.

Sweat glands. Sweat glands consist of (1) a body or secretory portion that may lie in the dermis or subcutaneous tissue, and (2) a duct which opens into the external surface of the skin (see fig. 1-2).

Sebaceous glands. Sebaceous glands, as seen in figure 1-2, are located on the lateral surfaces of the hair follicles. They secrete sebum, an oily substance, into the follicle. The sebum protects the hair from excessive dryness and brittleness and lubricates the skin surface.

Exercises (805):

Fill in the blank spaces with one appropriate word.

1. The outer portion of a nail is composed of the stratum ________.
2. The ____________ surface of a nail is composed of the stratum basale.
3. The hair ____________ is not normally visible.
4. A hair root is located inside the hair _____.
5. The secretory portion of a sweat gland may

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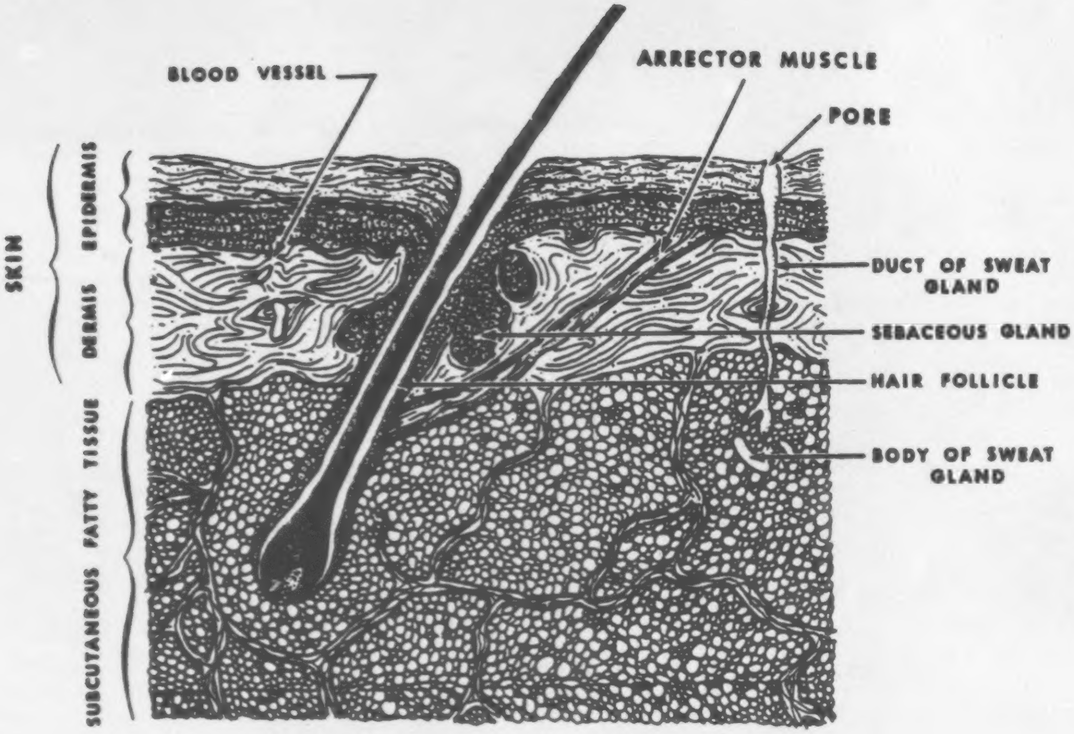

Figure 1-2. The epidermis, dermis, subcutaneous tissue, and appendages of the skin.

lie in the ____________ or ____________ tissue.

6. A sebaceous gland secretes ____________ which ____________ the skin surface.

1-3. The Endocrine System

The glands of internal secretion are commonly called "ductless" or endocrine glands because they secrete their hormones directly into the blood stream. (Other glands which secrete their products onto the body surface or into a body cavity are sometimes referred to as "duct" or "exocrine" glands.) The hormones secreted by the endocrine glands are important because they control many of our life processes.

In this section we will discuss the location and functions of the following endocrine glands: the *thyroid*, the *parathyroid*, the *thymus*, the *adrenal*, the *pituitary*, the *pineal*, the *pancreas*, and the *gonads*. Refer to figure 103 as we discuss their locations.

806. Given a list of the endocrine glands, identify each by function or characteristic.

Thyroid Gland. The thyroid gland is located in the anterior portion of the neck just below the level of the thyroid cartilage. It contains two lobes, the left and right, which are connected by a strip of tissue called the isthmus. The upper portions of each lobe follow the general contour of the lateral portions of the thyroid cartilage, which together with the thin isthmus give the thyroid a "butterfly" appearance. The hormone thyroxin is secreted by the thyroid gland. Thyroxin controls growth and development of the body by regulating the body metabolism.

Parathyroid Glands. The four parathyroid glands are located two on each lateral thyroid lobe—although their composition and function are completely independent of the thyroid gland. They appear as small oval discs averaging about 6 mm in length and 3.5 mm in width. The parathyroids secrete parahormone, which regulates the calcium content in the blood and the general calcific metabolic state in the body.

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Thymus. The thymus is located in the anterior portion of the upper mediastinum overlying the trachea and the major blood vessels arising from the heart. The thymus is larger in small children and undergoes a gradual reduction in size with age. It is thought that the gland secretes a substance that directs the production of antibodies that fight infections in the body.

Adrenal. The two adrenal glands located on the medial and superior aspects of the upper portions of each kidney consist of an outer section, the cortex, and an inner section, the medulla. The cortex produces several different corticosteroids which regulate salt, water, carbohydrate, protein, and fat metabolism. The medulla secretes adrenalin (epinephrine) and norepinephrine, which enable us to mobilize our body resources in times of emergency or stress.

Pituitary. The pituitary gland, sometimes called the "master" gland because it controls the secretions of various other glands, is located in the sella turcica. It is about the size of a "pea" and is comprised of an anterior and a posterior lobe. The anterior lobe dominates the functions of the pituitary by secreting hormones which affect many body processes. The following are examples of some of these hormones and their actions:

- Somatotrophin—Influences growth of body tissues.
- Thyrotropin—Influences the thyroid gland, causing it to secrete its hormone.
- Gonadotropin—Stimulates the gonads.

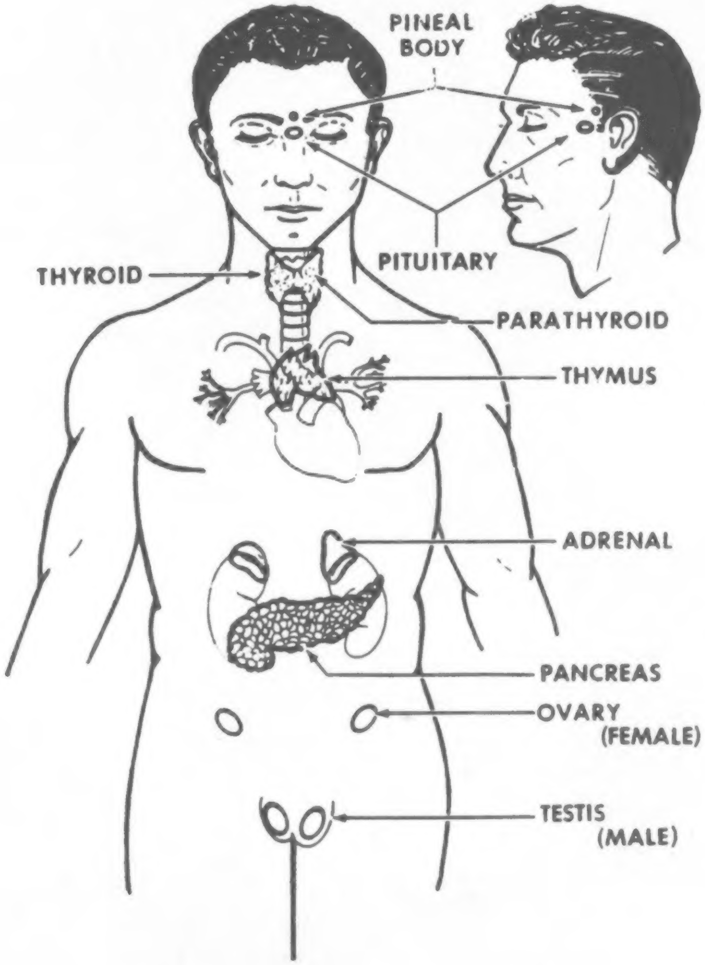

Figure 1-3. Locations of the endocrine glands.

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- Adrenotropin—Stimulates the adrenal glands.

An extract obtained from the posterior pituitary lobe acts upon certain muscle fibers, causing them to contract.

Pineal. The pineal body is located just posterior and superior to the pituitary, as seen in figure 1-3. The secretions and functions of the pineal are still somewhat uncertain.

Pancreas. The pancreas is considered to be both an exocrine and endocrine gland. Its exocrine function is the production of pancreatic juices for the chemical digestion of fats, carbohydrates, and proteins, which it empties into the duodenum. Its endocrine function is the secretion of insulin in the tiny island-like cells called the "Isles of Langerhans." Insulin regulates the sugar metabolism of the body.

Gonads. The gonads are the female ovaries and the male testes.

Ovaries. The ovaries produce several estrogens, which are hormones affecting development of the secondary sex characteristics. Estrogens also affect the reproductive functions of the female. One estrogen, progesterone, primarily functions to prepare the uterus for implantation of a fertilized ovum.

Testes. The testes produce androgens which are hormones affecting development of the secondary sex characteristics and maintenance of the reproductive functions. Two such hormones are androsterone and testosterone.

Exercises (806):

Match the endocrine glands in column B with the appropriate statement or phrases in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once, more than once, or not at all.

Column A

____1. Produce testosterone.
____2. Secretes insulin.
____3. Master gland.
____4. Secretes adrenalin.
____5. Controls body development.
____6. Shaped like a butterfly.
____7. Larger in small children.
____8. Secretes adrenotropin.
____9. Functions both as endocrine and exocrine gland.
____10. Produce progesterone.
____11. Produces corticosteroids.
____12. Four in number.
____13. Produces androsterone.
____14. Regulates calcific metabolism.

Column B

a. Thyroid.
b. Parathyroid.
c. Thymus.
d. Adrenal.
e. Pituitary.
f. Pineal.
g. Pancreas.
h. Ovaries
i. Testes.

CHAPTER 2

Field Radiography

IN ADDITION to "fixed" medical facilities, the Air Force maintains several field hospitals called Air Transportable Hospitals (ATH). These field hospitals are designed to be airlifted to almost any location and become operational in a matter of hours after arrival. Training in the operation of a field hospital comes from periodic exercises in which the equipment is transported to a site near the base, unpacked, assembled, inventoried, operated, repacked, and returned to the storage area. If you are assigned to one of these field hospitals, your primary job, obviously, is to set up and operate the radiology section. Most likely you will not be assigned to the ATH—that is, you will not be required to participate in a combat or other emergency deployment—until you have received appropriate training through the exercises mentioned above. However, due to unusual circumstances, you could possibly participate in actual operation of the hospital without prior on-the-job training.

This chapter is designed to familiarize you with some of the equipment with which you will be working in an ATH. Keep in mind that each major item of equipment comes with complete step-by-step illustrated instructions that show you how to assemble, operate, and disassemble the items. Unless you have worked repeatedly with these items, be sure to refer to the instructions.

This chapter consists of two sections. In the first section we will discuss the assembly of the two major items you will find in your field radiology section. The second section consists of operation of the X-ray apparatus and some specific guidelines about film processing.

2-1. Assembly of Equipment

The two major items of equipment you will be concerned with are the radiographic table and the 50/100 mA X-ray apparatus. We begin with the assembly of the table.

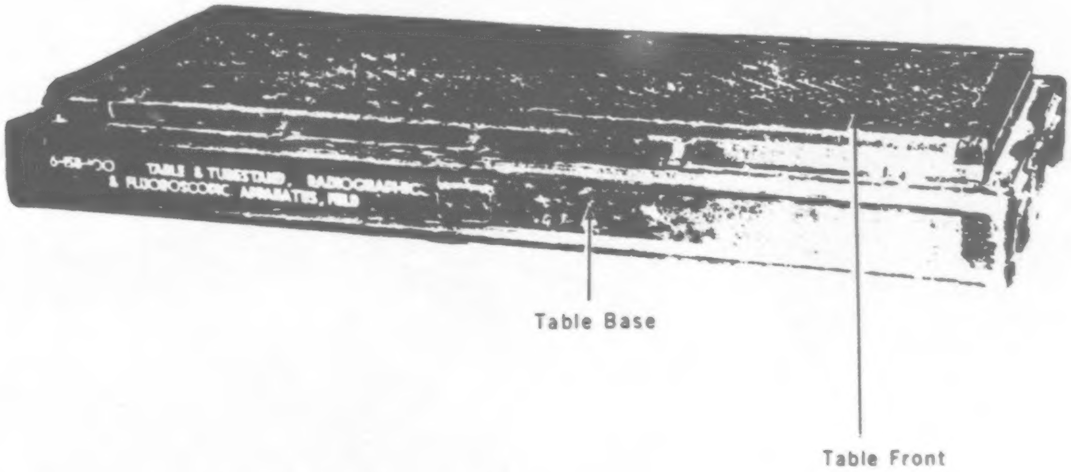
TABLE & TUBESTAND, RADIOGRAPHIC & FLUOROSCOPIC APPARATUS, FIELD
Table Base
Table Front

Figure 2-1. Front view of the field X-ray table completely assembled.

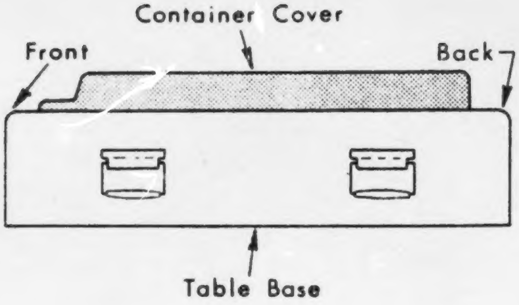

Figure 2-2. End view of the X-ray table container showing the front and back sides.

807. State the basic procedure for assembling the field radiographic table.

Field Radiographic Table. The field radiographic table, shown completely assembled in figure 2-1, weighs over 400 pounds. Due to its weight, there are two carrying handles on each end and one of each side. When carrying the table, use one person for each handle. Once assembled, the container cover shown in figure 2-1 serves as the table front. Before you open the container, position it in the exact location where it is to be used. Keep in mind that the front of the assembled table will extend about one foot beyond the front side of the container. Also position it so that the front side of the container is toward the area from which you will be working. The front side is identified on some containers. If it is not, you can tell the front by noting the shape of the container cover, as shown in figure 2-2.

After you have the container properly positioned, release the latches around the cover and remove it. Directly below the cover you will find the *tabletop*, as seen in figure 2-3. The tabletop is not fastened to the container in any way. Remove it and place it aside. At this point, you can also tell whether or not you have the container oriented properly with respect to the front and back. If you are standing in front of the container, the bucky unit is slightly to the left of center and the fluoroscopic screen is to the right of the center.

The next step is to attach the container cover to the front of the table base. Do this

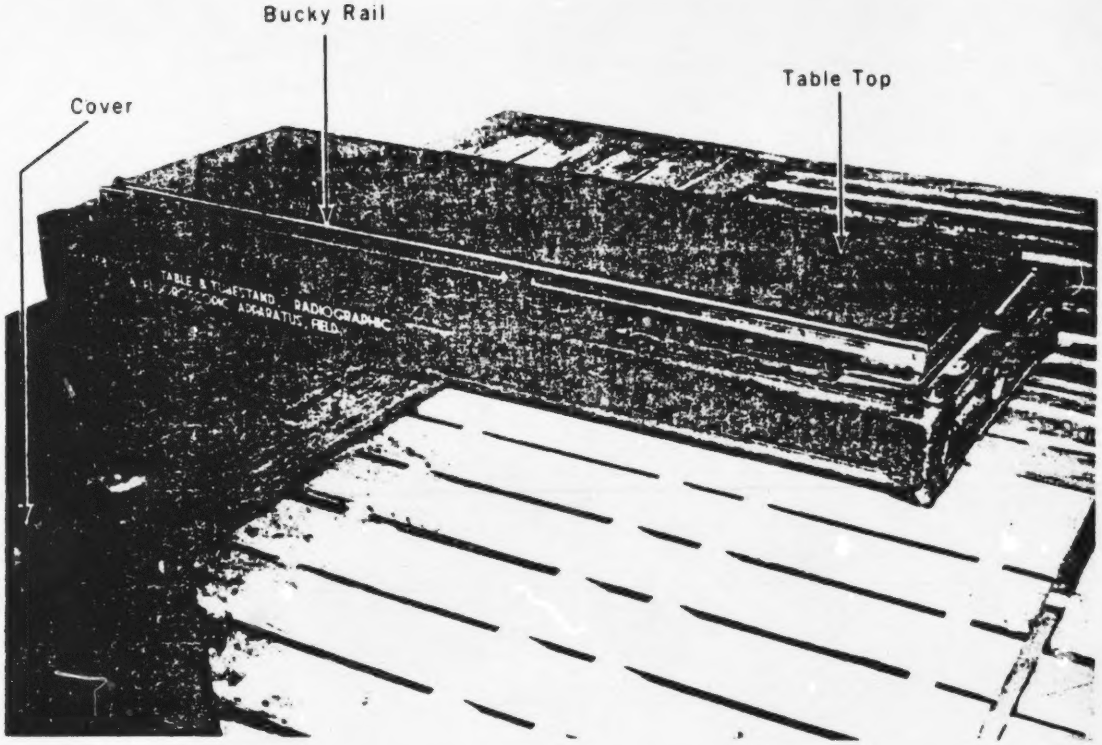
Bucky Rail
Table Top
Cover
TABLE & TUBESTAND, RADIOGRAPHIC
& FLUOROSCOPIC APPARATUS, FIELD

Figure 2-3. Front view of the X-ray table with cover removed.

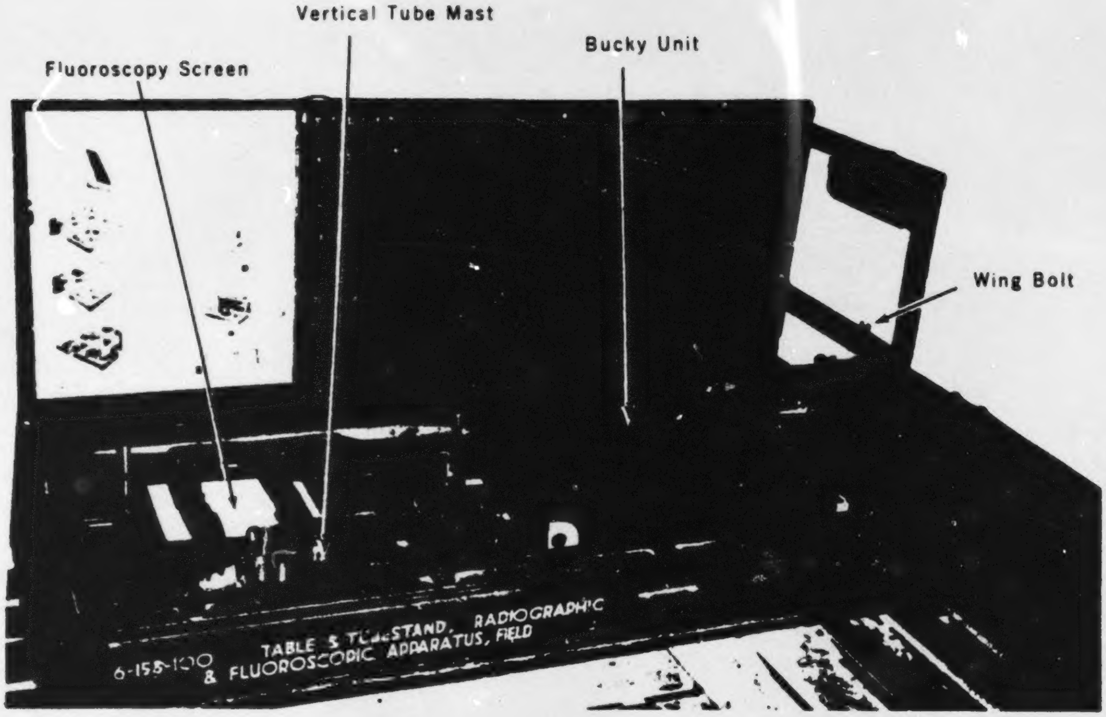
Vertical Tube Mast
Bucky Unit
Fluoroscopy Screen
Wing Bolt
6-155-100 TABLE & TUBESTAND, RADIOGRAPHIC
& FLUOROSCOPIC APPARATUS, FIELD

Figure 2-4. Back view of the X-ray table showing the cover attached to the table base.

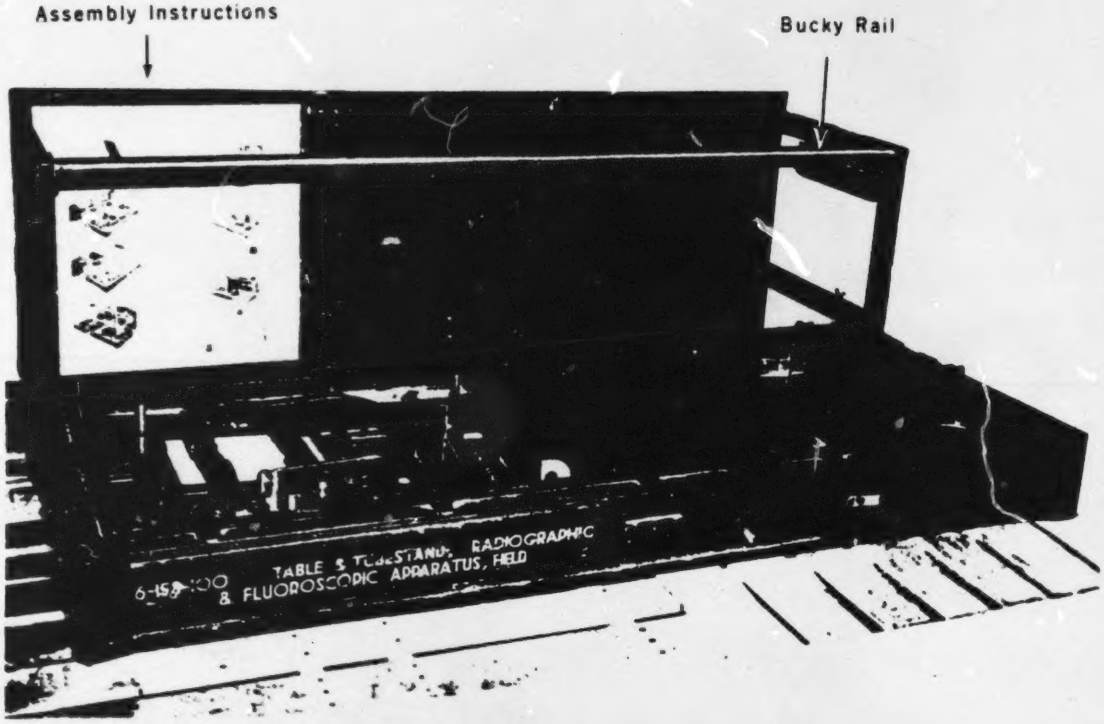
Assembly Instructions
Bucky Rail
6-155-100 TABLE & TUBESTAND, RADIOGRAPHIC
& FLUOROSCOPIC APPARATUS, FIELD

Figure 2-5. Back view of the X-ray table showing the bucky rail inserted into the end braces.

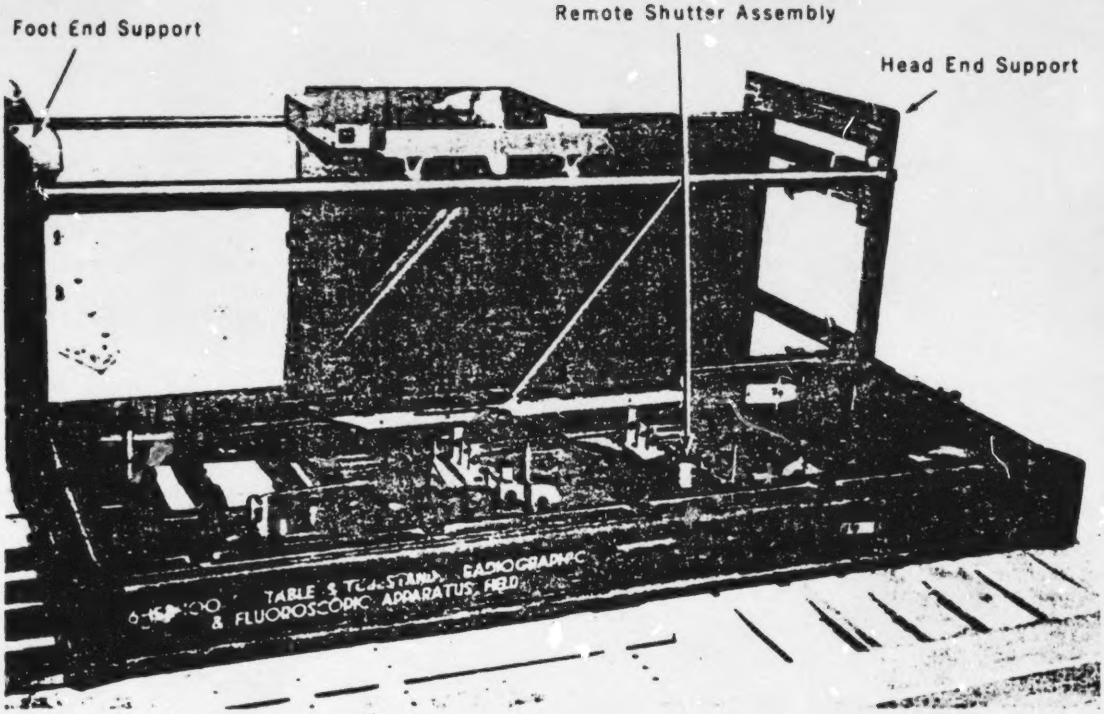

Figure 2-6. Back view of the X-ray table showing the bucky unit and foot and head end supports attached.

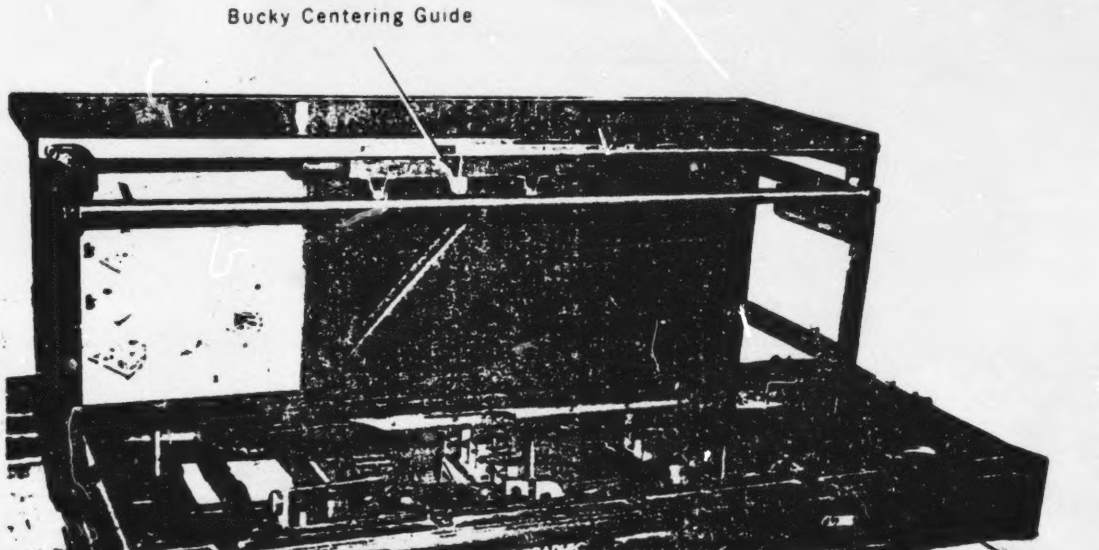

Figure 2-7. X-ray table with tabletop attached.

by releasing the end braces on the inside of the cover and attaching the braces to the front of the base using the wing bolts, as shown in figure 2-4. Notice that figure 2-4 shows the assembly from the back—consequently, the fluoroscopic screen is to the left, and the bucky unit is slightly to the right of center.

After securing the table front using the wing bolts, remove the *bucky rail* from the inside of the tabletop and insert it into the top back edges of the end braces, as shown in figure 2-5. Also notice in figure 2-5 that the assembly instructions are located on the inside of the container cover.

Next, remove the *bucky unit* and foot and head *end supports*, and attach them, as shown in figure 2-6. Then slide the metal grooves on the sides of the tabletop over the rollers on the foot-end support. Slide the tabletop to the head-end support and attach it to the head-end support using the two wing bolts (fig. 2-7).

Remove the *vertical mast* from the container and insert it into the mast receptacle located in the right, near corner of the base (as you look from the back). (See fig. 2-8.) Release the cloth straps and unfold or raise the mast. Lock the two sections of the mast together using the hinge lock, shown in figure 2-9. A V-shaped slot and vertical lock, also seen in figure 2-8, are present on the *swivel arm support*, located on the vertical mast. This slot receives the swivel arm containing the X-ray tube and collimator, fluoroscopic screen, etc. The vertical lock will not stabilize the swivel arm support until the entire unit has been assembled and is counterbalanced by the weight of the *swivel arm*, X-ray tube, etc. If the swivel arm is not properly stabilized, it may be pulled abruptly upward, damaging the top of the vertical mast, or injuring your hand. Therefore, do not attempt to lower the swivel-arm support until assembly is complete. Also, when you disassemble the unit, be sure to raise the swivel-arm support all the way to the top before removing the individual parts.

Finally, remove the swivel arm, fluoroscopic screen and fluoroscopic shutters. Insert the swivel arm into the V-shaped slot. (See fig. 2-10.) Attach the fluoroscopic screen and fluoroscopic shutters to the swivel arm. If you are using the 15 mA X-ray apparatus, attach the tube to the swivel arm, as shown in

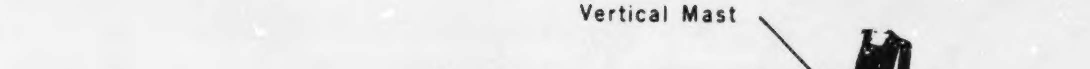
Vertical Mast
TABLE & TUBESTAND, RADIOGRAPHIC
& FLUOROSCOPIC APPARATUS, FIELD

Figure 2-8. X-ray table with vertical mast in place.

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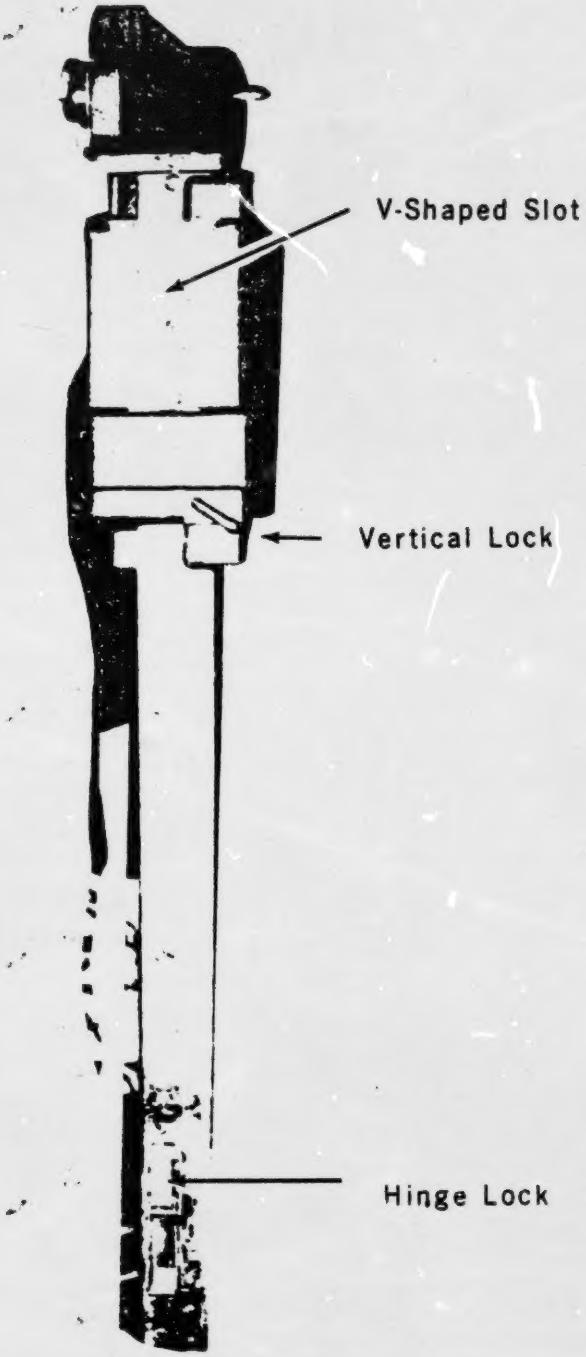

Figure 2-9. The vertical mast.

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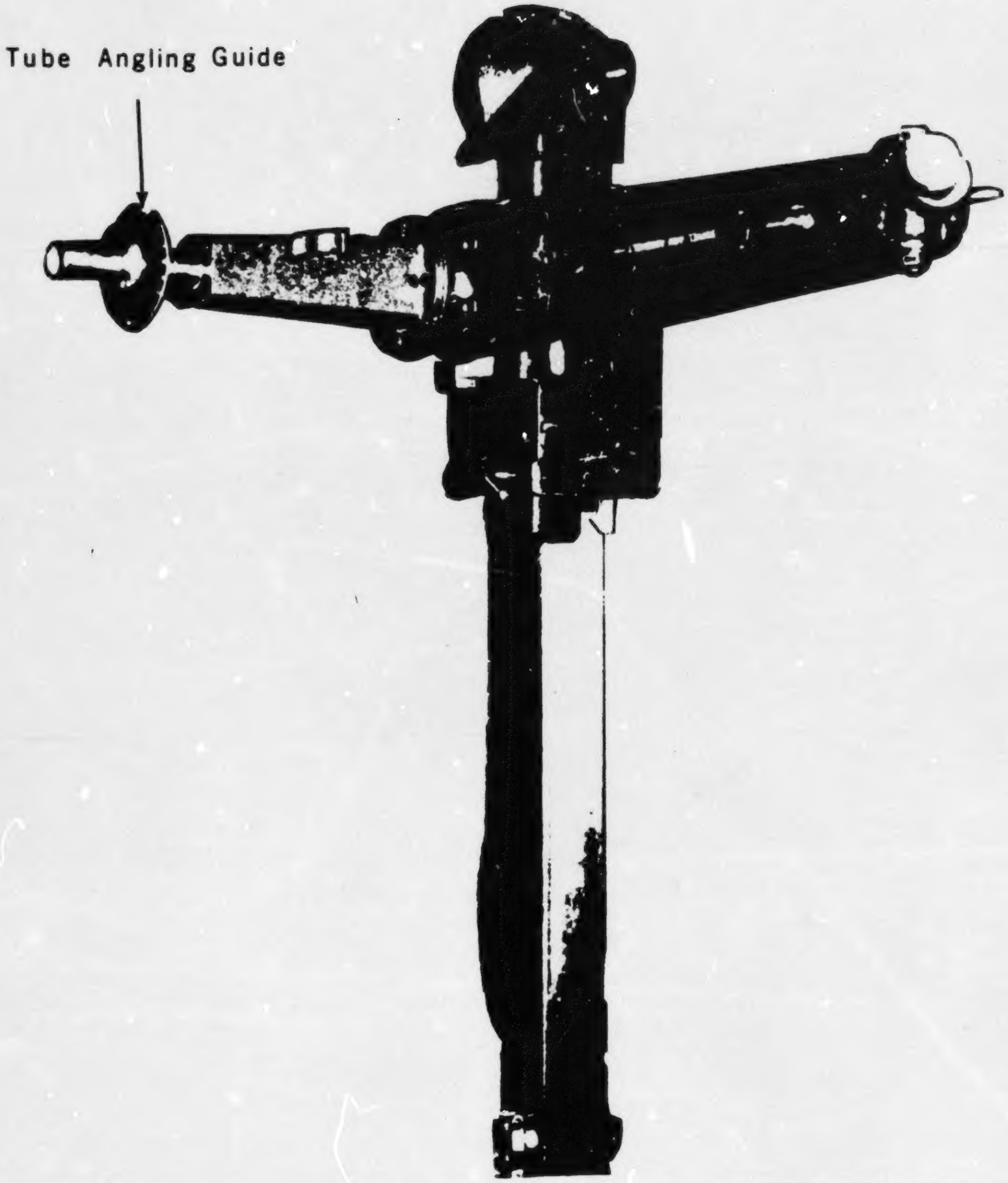

Figure 2-10. The swivel arm connected onto the vertical mast.

figure 2-11. Most likely you will be using the 50/100 mA X-ray apparatus, in which case the tube and collimator, shown in figure 2-12, will be attached.

Exercises (807):

1. How many persons should be used to carry the field radiographic table?
2. Briefly discuss placement of the table container before it is opened.
3. What part of the table is removed from the container after the cover?

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4. What initial part of the table assembly is connected to the table base?

5. Where will you find the bucky rail?

6. What parts are attached after the bucky rail is in place?

7. Discuss the precautionary measures you should take pertaining to the swivel arm support.

8. Name two X-ray units having tube heads that are compatible with the swivel arm of the field radiographic table.

9. Where are the manufacturer's instructions for assembling the field radiographic table located?

808. Identify the procedures for making the electrical connections of the transformer and rectifier of the 50/100 mA X-ray apparatus.

50/100 mA X-ray Apparatus. As indicated in the last text paragraph, the 50/100 mA unit is most likely to be used in field hospitals. The components of the unit are packed in five containers, shown in figure 2-13. The components are the high tension transformer, rectifier, X-ray tube, collimator, and control pane. CAUTION: Do not connect the power cord of this or any other unit to the power source until you have completely assembled the apparatus. Likewise, when

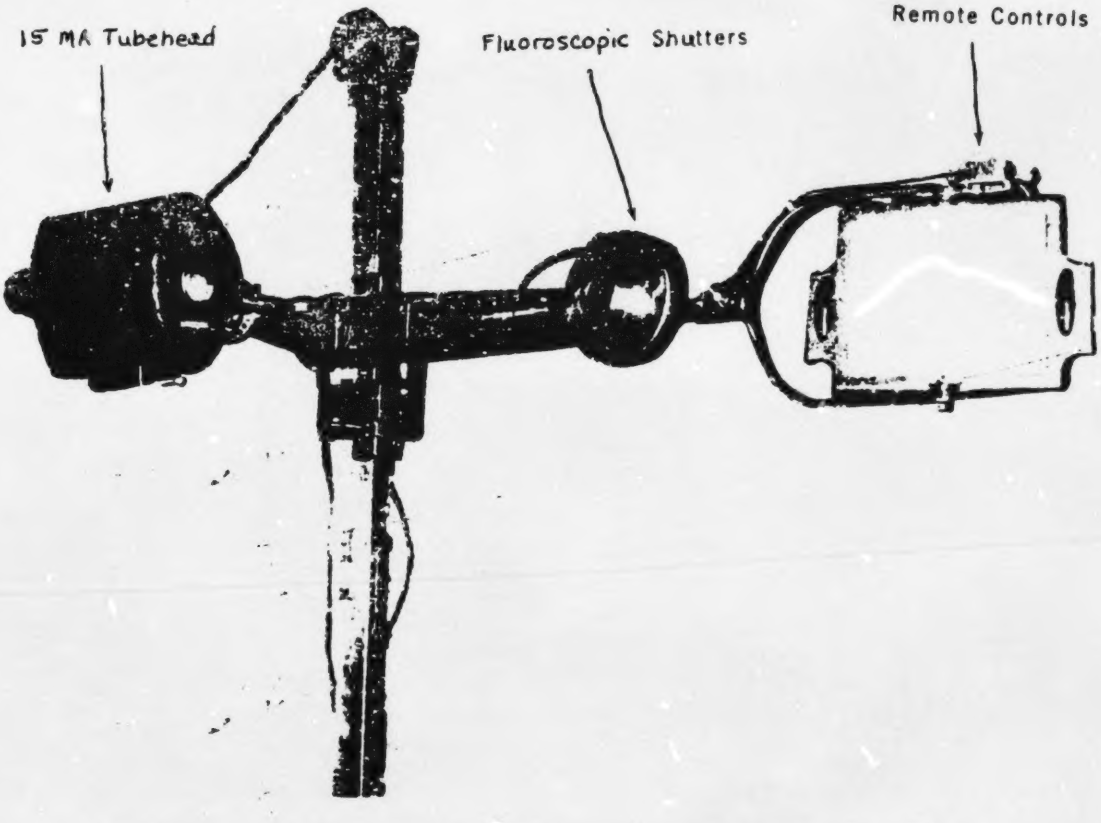

Figure 2-11. Swival arm with 15 mA tube, fluoroscopic shutters, and fluoroscopic screen attached.

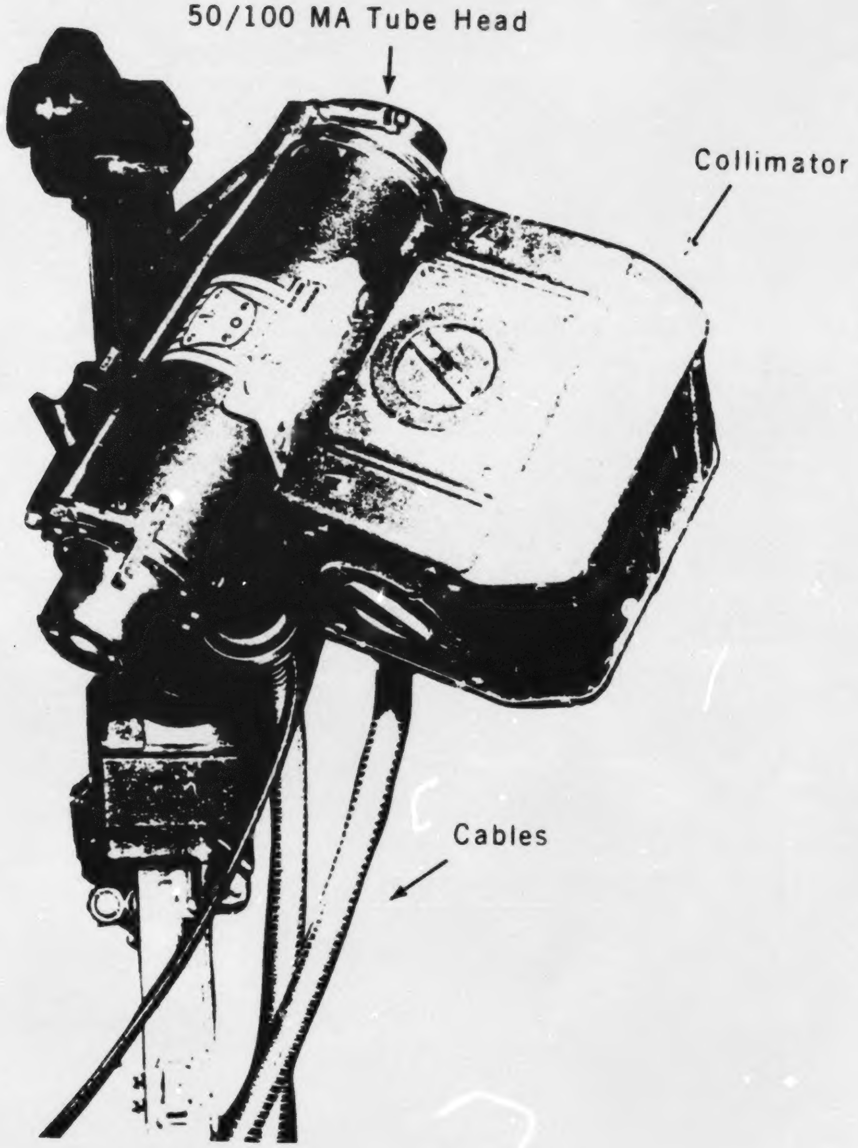

Figure 2-12. 50/100 mA tube and collimator connected to the swivel arm.

disassembling any unit, make sure you disconnect the main power supply first.

Transformer. The high-tension transformer, which must be used with this apparatus, is in a steel tank, which has been inserted into a steel-fabricated shipping chest. The transformer should always be shipped in the upright position. If laid on its side for a long period of time, it will lose some of its oil. An air breather is incorporated in the top of the transformer to allow for expansion of the oil due to heat. The transformer contains a short cable, one end of which is preconnected directly to the transformer. The free end of the cable contains a 10-pole, rectangular male plug. If you do not use the rectifier, insert the 10-pole plug into the appropriate receptacle, located on the back of the control panel. There is only one receptacle on the control panel which accommodates a 10-pole plug. It is labeled TRANS/RECT.

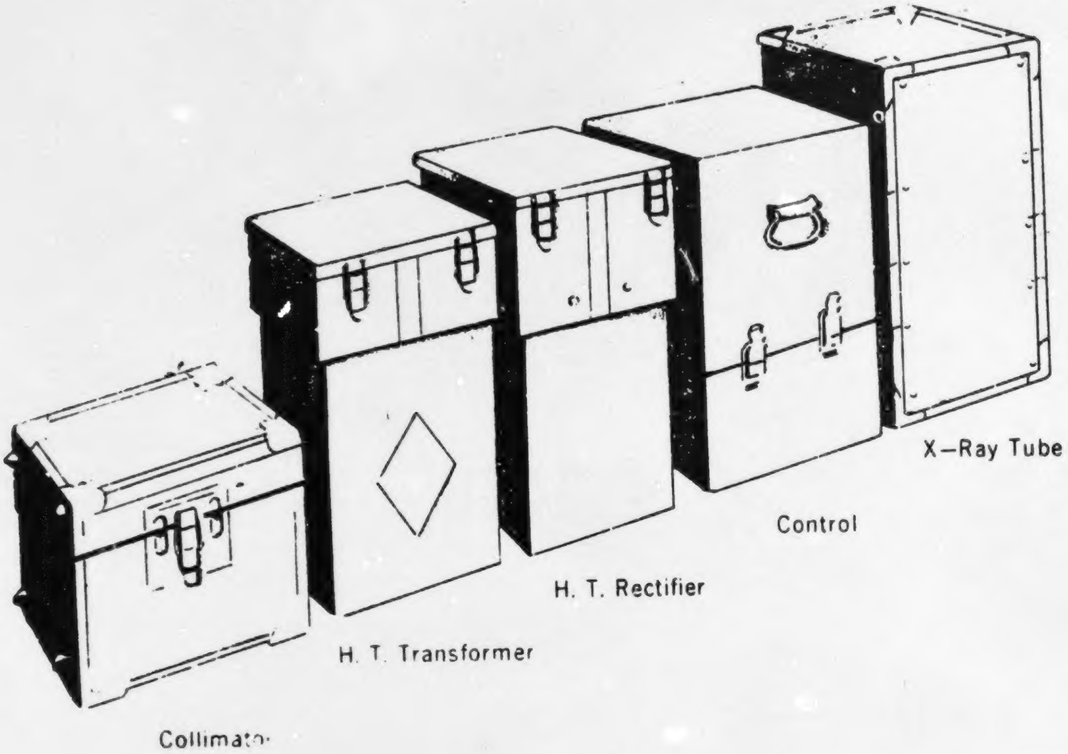

Figure 2-13. 50/100 mA X-ray apparatus—in containers.

The high tension transformer also has two cable jackets or sockets into which is inserted one end of each of the two high-voltage cables. (These cables are found in the X-ray tube container.) One of the sockets is labeled ANODE and the other is labeled CATHODE. The two high-voltage cables connect the transformer to the X-ray tube if the rectifier is not used. When connecting the transformer to the X-ray tube with these cables, be sure to maintain the polarity. For example, connect the end of one cable to the anode socket of the transformer and the other end of the *same* cable to the anode side of the tube. Follow the same procedure for the other cable with respect to the cathode socket of the transformer and the cathode side of the tube. Anode and cathode sides of the X-ray tube are clearly marked.

Rectifier. The rectifier is a companion unit to the transformer and is of similar size. When used, the rectifier provides full-wave rectification of the high voltage and approximately doubles the mA capacity of the unit and slightly increases the kVp capacity. For example, without the rectifier the unit is only capable of delivering 50 mA and 90 kVp using the large focal spot of a rotating anode tube. Under the same conditions, but with the rectifier, you can get 100 mA and 100 kVp.

The rectifier, like the transformer, contains a short cable, one end of which is preconnected directly to the rectifier. The free end of the cable contains a combination plug and receptacle. The male portion is a 10-pole device identical to that of the transformer. The female portion is a 10-pole receptacle and is identical to that of the control unit marked TRANS/RECT. To connect the rectifier into the unit, plug the male part of the combination plug into the control panel. Then plug the transformer cable into the female portion of the rectifier (combination) device.

The rectifier container also has two high-voltage cables—one end of each cable is preconnected directly to the rectifier. Insert the free ends of the cables into the anode and cathode sockets in the transformer. The sockets are the same ones through which you would have connected the X-ray tube to the transformer if you were not using the rectifier. When connecting these free ends of the rectifier cables to the transformer, polarity is not important--that is, either end may be inserted into either socket.

This leaves you with one final step in connecting the rectifier into the unit—that is, to connect the rectifier to the X-ray tube container. You do this with the high-voltage cables found in the X-ray tube container—the same cables with which you would have connected the transformer to the X-ray tube if the rectifier were not used. The rectifier, like the transformer, has two 5-cable sockets marked CATHODE and ANODE. Once again, polarity is important. Connect the cathode socket to the cathode side of the table, using the *same* cable. Likewise, connect the anode socket to the anode side of the X-ray tube, using the other cable.

Exercises (808):
Indicate whether the following statements pertaining to the procedure for performing the electrical connections of the transformer and rectifier of the 50/100 mA X-ray apparatus are true or false. If you indicate "false," explain your answer.

T F 1. You should not connect the power cord of this unit to the power source until the apparatus is completely assembled.

T F 2. You should disconnect the power cord before disassembling the unit.

T F 3. The 50/100 apparatus may be used without connecting either the transformer or rectifier--but not both.

T F 4. The cable sockets of the transformer are used to connect the transformer to the X-ray tube or to the control unit.

T F 5. The free end of the transformer cable connects to the control unit if you do not use the rectifier.

T F 6. You must maintain polarity between the transformer and X-ray tube.

T F 7. You must maintain polarity between the transformer and rectifier.

T F 8. Connecting the rectifier into the circuit approximately doubles the unit's mA capacity.

T F 9. You need *NOT* maintain polarity between the rectifier and the X-ray tube.

T F 10. If the rectifier is connected into the circuit, the free end of the transformer cable should be connected directly to the control panel.

809. Briefly state the procedure for assembling the control unit stand; list and indicate the purpose of each of the receptacles located on the back of the control unit.

X-ray tube, collimator, and control unit. The control unit and the other cables necessary to connect the 50/100 mA unit are in the same container. Unfasten the draw bolts, remove the top cover of the control unit container, and place the cover on the ground with the open end up. Remove the control panel from the lower section of the container and take out the electrical cables. Set the bottom portion of the chest open end up on the top of the inverted top section and fasten them together with the draw bolts. Place the control unit on top of the stacked container stand, as shown in figure 2-14. As you can see in the figure, there are five receptacles on the back of the control unit. From the left, the first receptacle (TUBE) is used to connect the control unit to the X-ray tube and collimator. The tube end of the cable contains two plugs—one plugs into the tube head above the blower, and the other

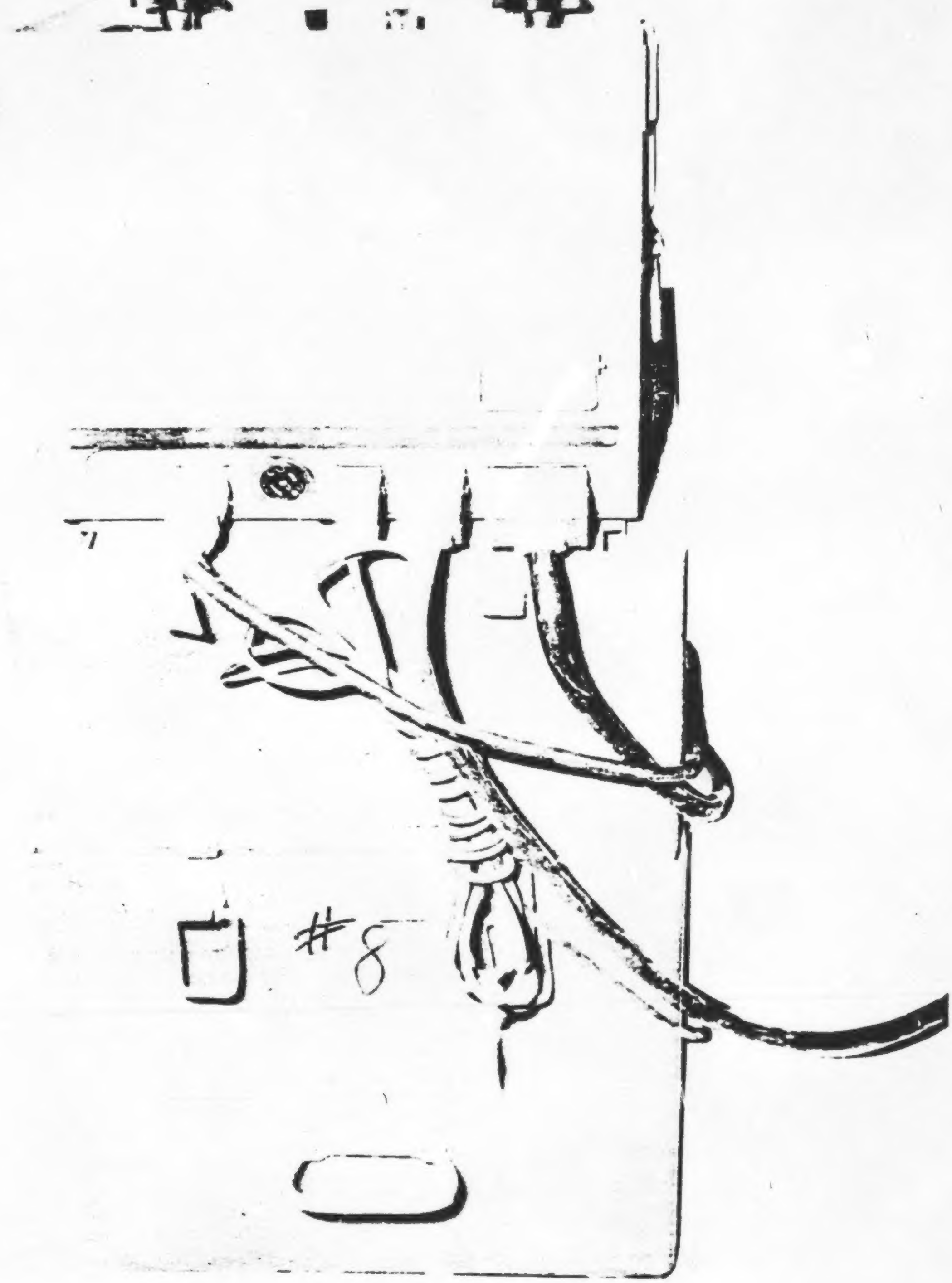

Figure 2-14. 50/100 mA control unit (rear view).

812. Indicate the maximum mA, kVp, and exposure time allowed on the 50/100 mA X-ray apparatus.

mA, kVp, and exposure time values. The maximum mA, kVp, and time you should use on this unit depend upon several factors. As you can see in figure 2-16, the technique selector (D) indicates various maximums, depending on such factors as anode characteristics (stationary or rotating) and rectification (self- or full-wave). Notice also that the technique selector has three settings: (1) FLR—fluoroscopy, (2) RSF—radiography, small focus, and (3) RLF—radiography, large focus (the selector is set on RLF). To these influential factors, we must also add the line voltage. If the line voltage is in the 110-volt range, you should not use more than 90 kVp and 30 mA if the unit is self-rectified, or 58 mA if you are using the rectifier. The reason is that higher mA settings would result in a relatively high voltage drop, causing your actual voltage across the tube to be excessive. When you set you kVp before the exposure, the voltage is indicated on the kilovolt meter (C) in figure 2-16. However, the voltage indicator is not the voltage across the tube during exposure. The only way you can determine the actual tube voltage during the exposure is to read the voltage on the meter *while* the exposure is in progress. The difference between that reading and your preset voltage equals the voltage drop. Most likely, the tube voltage will be less than the preset voltage. As a rule, the voltage drop should be 5 kVp or less. If it is more, your mA is too high for the existing conditions.

Exercises (812):

1. Name three factors indicated on the control unit of the 50/100 mA apparatus which affect the *radiographic* technique capacity of the unit.

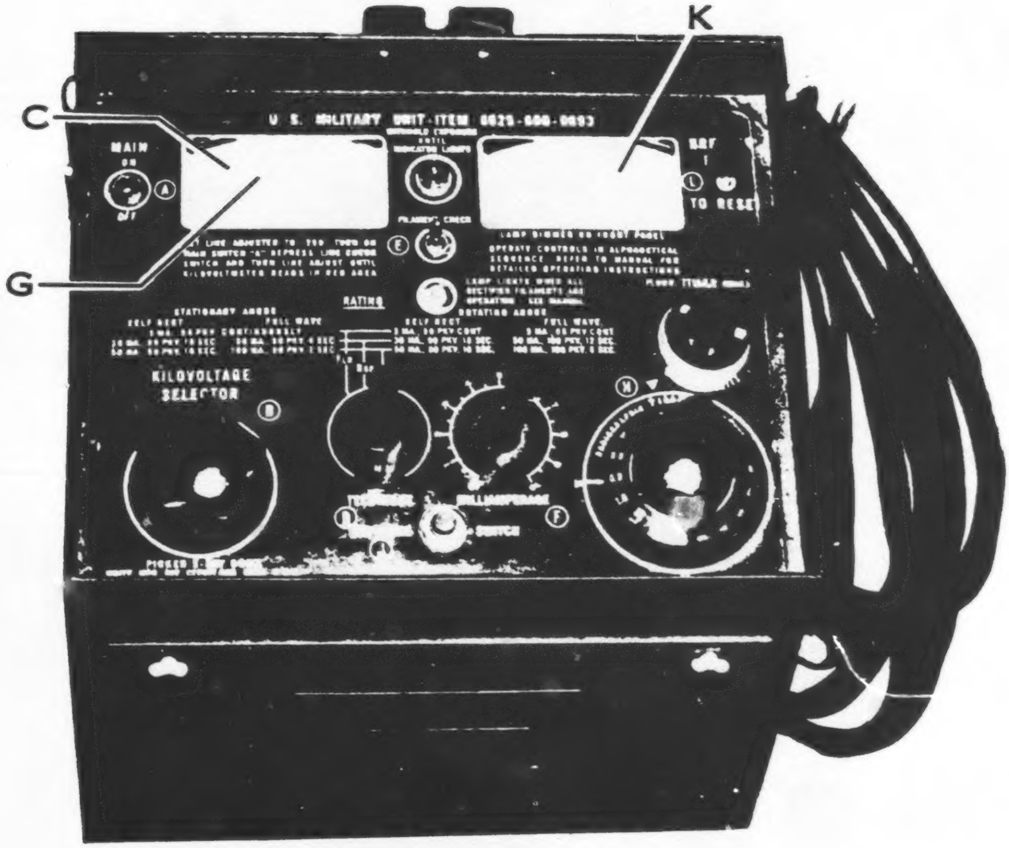

Figure 2-16. Control panel—top view.

2. Regardless of the information provided on the control panel, what maximum mA and kVp values should be used on a 110-volt power line?

3. Why are the limitations indicated in exercise #2 (above) necessary?

4. How do you determine your voltage drop across the X-ray tube?

5. If the voltage drop is more than 5 kVp, what does the condition indicate?

813. Indicate the procedures for adjusting and evaluating the mA on the 50/100 mA control panel.

Adusting the mA. There are four parts of the control panel in figure 2-16 that must be considered when adjusting or selecting your mA for an exposure: (1) the mA meter (K); (2) the mA adjuster (F); (3) the filament scale (G); and (4) the filament check switch (E). The mA meter has two scales—the top scale shows the radiographic mA, and the bottom scale shows the fluoroscopic mA. The meter only reads the mA under load (during the exposure). Also, both scales have a red danger-zone area—do not operate the mA in these zones. The mA adjuster simply adjusts the mA. The filament scale (lower scale on the meter) allows you to adjust the mA without making an exposure, since the mA meter reads the mA only during exposure. The filament check switch merely activates the filament scale.

Basically, the mA is adjusted or selected as follows: Let's assume you have your machine red-lined, and the technique selector is set on radiography. Turn the mA adjuster to its lowest setting—fully counterclockwise—and set the kVp selector to a low value. Set the radiographic timer to 3 or 4 seconds. Make an exposure. Immediately after the exposure begins, turn the mA adjuster clockwise until the mA reaches a specified value—for example, 30 mA. Keep in mind that the mA meter registers only under load; therefore, you will have to make the adjustment rather quickly. You could use a longer exposure, but this might also overload the tube. If you must use more than one exposure, allow a short period for the anode to cool. After you have the mA adjusted to our example of 30 mA, depress and hold the filament check switch and check the filament scale. Let's assume the needle registers 5.5. Release the filament check switch, and the needle will return to indicate the preset kVp value. At this point, you can repeat the procedure and find the filament scale values for other mA values. You might end up with a working filament chart like the following:

Filament Scale	*mA*
2.5	10
3.0	15
4.0	20
5.5	30

Now suppose you are ready to begin X-raying patients and you want to use 30 mA for your first patient. All you have to do is depress and hold the filament check switch and turn the mA adjuster until the needle indicates 5.5 on the filament scale. Release the filament check switch, and your exposure will be made at 30 mA. If you want to use 20 mA, turn the mA adjuster until the needle reads 4.0 on the filament scale, and so on.

Exercises (813):

1. What is the significance of the red zones on the mA meter?

2. When does the mA meter reflect the correct mA?

3. What is the purpose of the filament check switch?

4. Assume that you have just set up your machine in the field and have it properly red-lined with the technique selector on radiography. You want to find the filament scale value that indicates 25 mA. How do you go about it?

5. How can you build yourself a working filament chart?

6. Suppose your filament chart is as follows:

Filament Scale	*mA*
3.5	25
5.5	40
6.5	50

Further suppose you want to use 50 mA for a radiograph.

Explain how you set the correct mA on the control unit.

814. State the names and characteristics of the three types of Polaroid films, and indicate how to correct improperly exposed Polaroid radiographs.

Polaroid Processing. The Polaroid processor and special film allow you to process radiographs in as little as 10 seconds without the use of a darkroom and "wet" processing tanks. This type of processing is particularly useful in the field, where facilities for wet processing are limited. At this point in your training, you should know how to load the special cassette and process the film. Also, detailed step-by-step instructions for these procedures are included with the unit if review is necessary. Consequently, our discussion is mostly concerned with the film itself.

Types of Polaroid films. Currently these types of the special film are available: (1) *1001*, (2) *3000X*, and (3) *TLX*. The 1001 and 3000X are processed for 60 seconds and 10 seconds, respectively. The TLX is processed for 45 seconds. After processing, the 1001 and 300X are viewed by reflected light much the same as you would view a photographic print because the image is present on a paper base. The TLX, on the other hand, may be viewed by the same means as the other two types, or it may be viewed by transmitted light using a viewbox. Both viewing methods are possible because the film base is made of polyester.

Exposure considerations. The radiographic image recorded on the special film is the opposite from that recorded on conventional film. By "opposite," we mean that it is positive rather than negative. Consequently, bone appears dark on a light background. The significance is that an overexposed image appears too light while an underexposed image appears too dark. This, of course, is opposite from the appearances of overexposed and underexposed conventional radiographs and requires opposite exposure corrections. When making these corrections, do so by altering the mAs rather than the kVp

As a rule, film contrast is somewhat lower on Polaroid film than on conventional film. The low contrast is an inherent characteristic of the film and to some degree must be tolerated. However, in specific cases where high contrast is desired, you can partially offset the film characteristic by using low kVp as long as adequate penetration and density are not sacrificed.

Exercises (814):

1. Name the three types of Polaroid film.

2. For what period of time should each type of Polaroid film be processed?

3. How may you view each type of Polaroid film?

4. If a Polaroid radiograph is too dark, how would you correct the exposure on a subsequent radiograph?

5. How can you increase the contrast on a Polaroid radiograph?

CHAPTER 3

Radiation Therapy

AS FAR AS you are concerned, radiation therapy is limited to X-ray therapy—that is, treatment of diseases using X-rays, as opposed to treatment using gamma or other types of radiation. X-rays, as you know, are produced when high-speed electrons interact with a target, whereas gamma radiation, alpha particles, and beta particles are products of the decay of radioactive nuclides. The use of nuclides or isotopes for treatment is part of the job description of AFSC 909X0 Nuclear Medicine Specialist/Technician.

If you are assigned to one of the larger Air Force hospitals where radiation therapy is provided, you may be required to work in the therapy section. Chances are you may have been exposed to some practical training in therapy procedures as a result of your Phase II training. Therefore, you should realize by now that your role is somewhat different from that of a diagnostic technician. In therapy, you are more of an assistant to the radiologist; whereas when performing most diagnostic examinations you are "on your own," so to speak.

Specific theraputic procedures, like diagnostic procedures, vary—depending upon the equipment in use and the radiologist's approach to the treatment. For these reasons, this chapter will be generally oriented toward principles rather than specific procedures.

3-1. Introduction to Radiation Therapy

In this section we will discuss the basis and purpose of radiation therapy and some general terms.

815. Give the basis and purpose of radiation therapy.

Basis and Purpose of Radiation Therapy. Penetration and ionization are two important characteristics of radiation which make it useful in the treatment of disease. Since radiation can penetrate body tissues, it obviously has the capability to reach into areas where pathological processes may exist. When radiation is directed toward an area of the body containing pathology, ionizations occur in the normal, as well as the abnormal, tissues. The ionizations produce biological changes in both normal and abnormal cells. These biological changes, in part, damage or control the growth of both types of cells; however, the response to the radiation is not entirely the same. As a rule, abnormal cells are more sensitive to radiation than normal cells. Radiation therapy is based on this differential response of cells to radiation. By carefully subjecting the cells to radiation, radiologists aim to damage or control the growth of abnormal cells; while, at the same time, they aim to spare the surrounding normal or healthy cells.

Exercises (815):

1. What is the basis of radiation therapy?

2. What is the purpose of radiation therapy?

816. Differentiate between benign and malignant tumors.

Tumors. The word "tumor" encompasses a broad spectrum of growths. Generally, we can categorize all tumors as *benign* or *malignant*.

Benign. A benign tumor is one that exists only in its immediate site of growth. It is usually enclosed in a capsule that prevents it from spreading to a remote site. Benign tumors are, for the most part, less dangerous because they can be totally removed by surgery. In some cases, however, they can become dangerous. An example of a dangerous benign tumor is one growing and spreading in the region of the brain. Having no room to expand, it damages the surrounding brain tissues as it grows. Benign tumors are *usually* not treated with radiation.

Malignant. A malignant tumor is a growth that may cause damage at the place where it first appears; and it may spread to other locations within the body, also causing damage to the remote sites. This "spreading" of a malignant tumor is called *metastasis.* The initial growth is called a *primary* tumor, while a growth resulting from metastasis is called a *secondary* or metastatic tumor. Most radiation therapy is directed toward malignant tumors.

Tumors may spread by one of three methods: (1) direct local spread, (2) by way of the lymphatic system, or (3) by way of the circulatory system. Direct local spread implies that the tumor grows directly from its original site and invades surrounding organs or tissues. When a tumor spreads by way of the lymphatic system, tumor cells enter the lymphatic system and are carried along the lymphatic ducts, and either become lodged in a duct or in a lymph node, where a secondary tumor is formed. Tumor cells may also move from the secondary tumor and form other secondary tumors. Malignant tumors spreading by way of the circulatory system do so in a manner similar to those spreading through the lymphatic system. In this case, secondary tumors may form in virtually any of the body tissues, although certain metastatic sites are more common than others.

Exercises (816):

Match the type of tumor in column B with the appropriate statement or phrase in column A by placing the letter of the column B item in the space provided in column A. Each column B item may be used once or more than once. In addition, both column B items may match a single column A entry.

Column A	*Column B*
__1. Growth.	a. Benign.
__2. May cause damage at remote location.	b. Malignant.
__3. More dangerous.	
__4. Enclosed in a retaining shell.	
__5. Secondary lesion.	
__6. Moves via the circulatory system.	
__7. Radiation therapy is usually directed toward this type.	
__8. Causes damage by direct local spread.	

817. Name and briefly assess two factors influencing the success of tumor treatment by radiation and identify the two types of radiation treatment.

Types of Tumor Treatment. Not all malignant tumors can be successfully treated with radiation therapy. The success of the treatment depends upon several factors. One of the influential factors is the sensitivity of the tumor tissue to radiation—some tissues are more sensitive, or *radiosensitive;* others are less sensitive, or *radioresistant.* The more sensitive the tumor, the greater the chance for successful treatment. Another factor influencing the outcome of the treatment is the stage of development in which treatment is initiated. Early treatment increases the chance for success. Generally, treatment of tumors can be classified as "radical" or "palliative."

Radical. Radical treatment of a tumor means that an attempt is made to cure the patient. By "cure," we mean that for 5 years from the time of treatment the patient remains alive and well with no sign of the disease.

Palliative. Palliative treatment is reserved for those patients whose condition has deteriorated to the point where a cure is not possible. The treatment is usually oriented toward the patient's symptoms and may be of significance in reducing pain or enhancing some basic function, such as breathing or swallowing, if a tumor interferes with that function.

Exercises (817):

1. Name two factors influencing the success of radiation treatment. In each case briefly discuss how the treatment is effected.

2. What is radical treatment?

3. When is the patient considered to be cured?

4. What is palliative treatment?

818. Given written descriptions of three combination therapy filters, indicate whether or not the order of the filters is correct; if incorrect, state the consequences.

Filtration. Filters are used in therapy for the same basic reason as they are used in diagnostic radiology—that is, to remove the long wavelength or low-energy photons. In the case of the radiographs, the low-energy photons increase the dosage to the patient and do not contribute to the exposure of the film. In the case of therapy, they increase the patient's skin dose and do not contribute to the treatment of the pathological process. Most commonly tin (Sn), copper (Cu), and aluminum (Al) are used as filters for therapy—individually or in various combinations.

When using a combination of filters, always place the material with the highest atomic number closer to the tube. The reason is that the higher the atomic number of the material, the higher the energies of the characteristic photons emitted by that material. High energy characteristic radiation may reach the patient and increase his skin dosage while offering little toward treatment of a tumor. For example, if a combination of copper and aluminum are used, copper with the highest atomic number emits characteristic photons with higher energies than those of aluminum. By placing the two filter layers so that the copper is nearer the tube, copper's characteristic photons are absorbed by the aluminum. The characteristic photons emitted from the aluminum possess too little energy to reach the patient and are absorbed in air. A common therapy made up of a combination of copper, aluminum, and tin is called a Thoraeus filter. Tin has a higher atomic number than copper or aluminum.

Exercises (818):

Below are listed three descriptions of combination therapy filters. Indicate whether or not the order of the filters is correct. If the order is incorrect, briefly discuss the consequences of the arrangement.

1. 1 mm aluminum + 0.5 mm copper. The layer of aluminum is placed toward the patient with the copper nearer the tube.

2. The same filter materials as in exercise 1 above with the copper toward the patient.

3. 1 mm aluminum + 1 mm tin + 1.5 mm copper. The aluminum is nearest the patient, and the tin is nearest the tube.

3-2. Dosage Calculation Factors

Dosage calculations are based on factors that may be measured directly in the primary beam, or indirectly by using a phantom. The first factor that we will consider is the determination of the quality of the therapy beam. After that, we will proceed with the calculation of the dosage.

819. Define the term that describes the quality of a therapy beam, and apply it to compute the value of given beams.

Beam Quality. Generally, in diagnostic radiology we think of the quality of the primary beam in terms of the kVp setting on the machine. For example, we know that 85 kVp adequately penetrates certain body structures and produces diagnostic radiographs of those structures. In therapy, it is not practical to describe the quality of the beam in terms of the kVp alone because the variations between the output of different machines, using the same kVp, is sufficient to produce beams with different treatment potentials.

The quality of a therapy beam is usually described in terms of its ability to penetrate some material of known composition. This penetrability is expressed as the beam's "half-value layer." The half-value layer is the thickness of some standard material required to reduce the intensity of a beam to one-half its original value.

For example, to describe the quality of a 15-mA, 200-kVp, X-ray beam with a 1 mm Al + 0.25 mm Cu + 1 mm Sn filter added, it is necessary to measure the output of the tube in roentgens per minute (R/min) at some standard distance, usually 50 cm. The next step is to determine how thick of an absorber must be used to reduce the output to one-half the original reading at the same distance. In this case, we might find that it takes 1 mm of Cu to reduce the dose rate from 60 R/min to 30 R/min. These results would mean that the beam has a half-value layer of 1 mm Cu. Keep in mind that the 1 mm Cu is not a filter and is not used during treatment. It is only used to determine the quality of the beam. Naturally, the greater the thickness of the necessary material to reduce the intensity to one-half, the higher the beam quality or the greater its penetrative ability.

Exercises (819):

1. What term is used to describe the quality of a therapy beam? Define the term.

2. Why is the quality of a therapy beam not described by the kVp setting?

3. What is the half-value layer of the following beams?
    (1) 15 mA, 200 kVp, 90 R/min at 50 cm using a Thoraeus filter:
    75 R/min at 50 cm, with 0.25 mm Cu added
    60 R/min at 50 cm, with 0.50 mm Cu added
    45 R/min at 50 cm, with 0.75 mm Cu added
    (2) 15 mA, 150 kVp, 40 R/min at 50 cm using a Thoraeus filter:
    30 R/min at 40 cm with 0.15 mm Cu added
    20 R/min at 40 cm with 0.25 mm Cu added
    20 R/min at 50 cm with 0.50 mm Cu added

820. Given the air dose rate of a therapy beam at a specified distance from the focal spot, determine the air dose rate (in R/min) of the same beam at other distances.

Air Dose Rate. The next step in calculating the dosage is to measure the *air dose rate*. The air dose rate is the intensity, without interference from backscatter, of the beam in air at a given distance from the focal spot. In figure 3-1, the reading taken at a point 50 cm from the focal spot of the tube indicates an air dose of 60 R/min. In figure 3-2, notice that the two readings show that the air dose rate drops as the distance from the focal spot is increased. The obvious reason for the drop is that the air dose rate is affected by distance from the focal spot the same way that beam intensity is affected in your diagnostic radiation beam. In both cases, if an initial measurement is made, the inverse square law may be applied to determine the intensity at any distance.

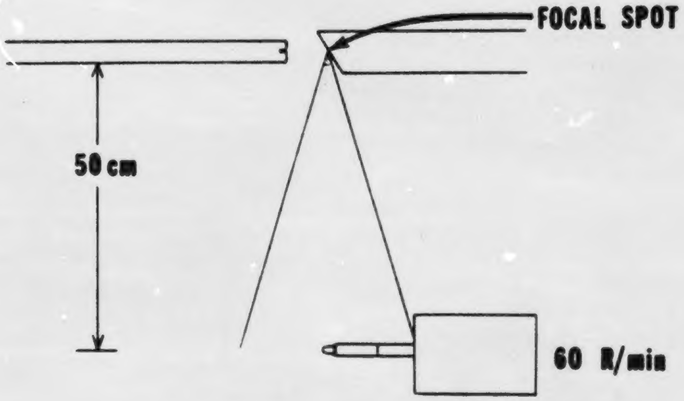

Figure 3-1. Measurement of air dose rate.

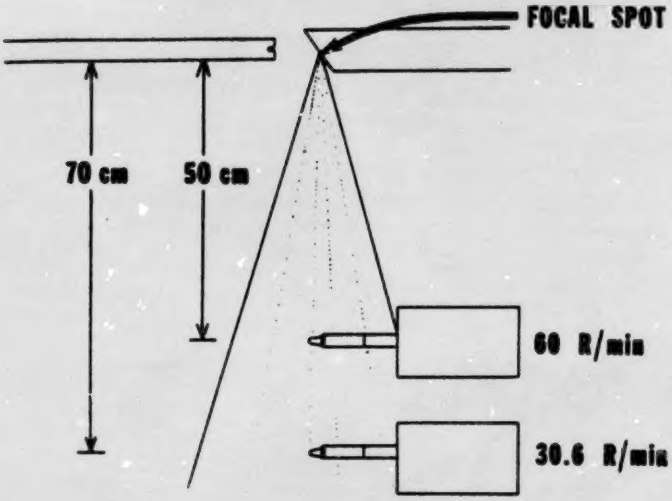

Figure 3-2. Comparison of air dose rates at 50 cm and 70 cm from the focal spot.

To find the air dose rate at any distance from the focal spot after an initial reading, use the following formula:

$$I_2 = \frac{(I_1)(D_1)^2}{(D_2)^2}$$

where:

I_1 = the original measured air dose rate
I_2 = the air dose rate in question
D_1 = the distance from the focal spot to where the original air dose rate was measured
D_2 = the distance from the focal spot to I_2 above

For example, we could have determined the air dose rate at 70 cm in figure 3-2 without a direct measurement, as follows:

$$\begin{aligned} I_2 &= \frac{(I_1)(D_1)^2}{(D_2)^2} \\ &= \frac{(60)(50)^2}{70^2} \\ &= \frac{(60)(2500)}{4900} \\ &= \frac{150000}{4900} \\ &= 30.6 \text{ R/min} \end{aligned}$$

Exercises (820):

Suppose a therapy beam provides an air dose rate of 85 R/min at 50 cm from the focal spot. Based on this information, answer the following exercises:

1. What is the air dose rate at 60 cm?

2. What is the air dose rate at 35 cm?

821. State the effect of backscattering of therapy beam photons on the surface dose rate, define backscatter factor, and given the necessary figures, determine the radiation dose rate (in R/min) to the patient's skin under specific treatment conditions.

Determining Dosage Rates With a Phantom. After the half-value layer and the air dose rate have been determined, the next step is to determine what the radiation dose rate would be if our X-ray beam were directed toward a patient at a given distance from the tube (focal spot). Obviously we cannot place a meter at various points within the patient to determine the dose rate, so we must make the measurements using a *phantom*. Phantoms are usually made of "tissue-equivalent" materials which have radiation absorption and scatter characteristics similar to that of soft tissue. However, many types of phantoms are available, and the type selected depends upon the purpose for which the measurement is taken.

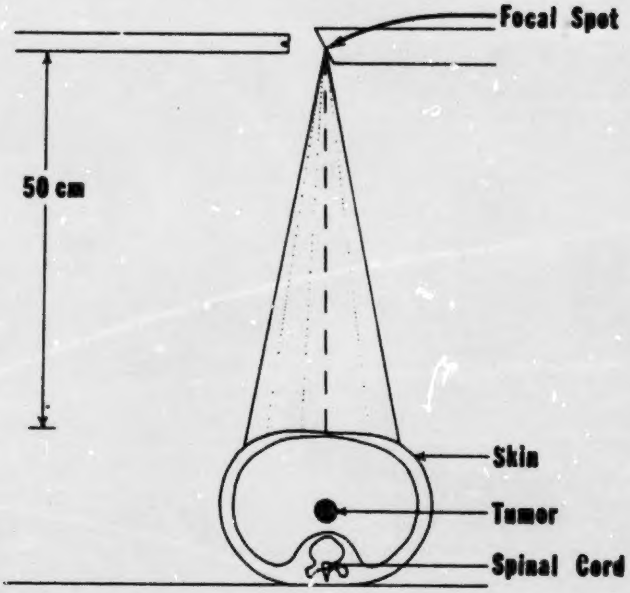

Figure 3-3. Cross-section view of a tumor in a patient to be treated by radiation.

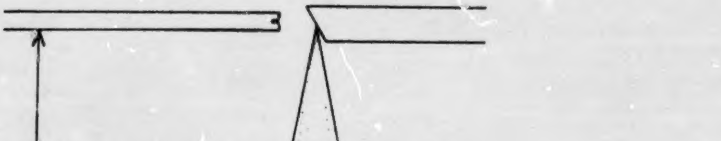

Figure 3-4. Measurement of the surface dose rate with a phantom.

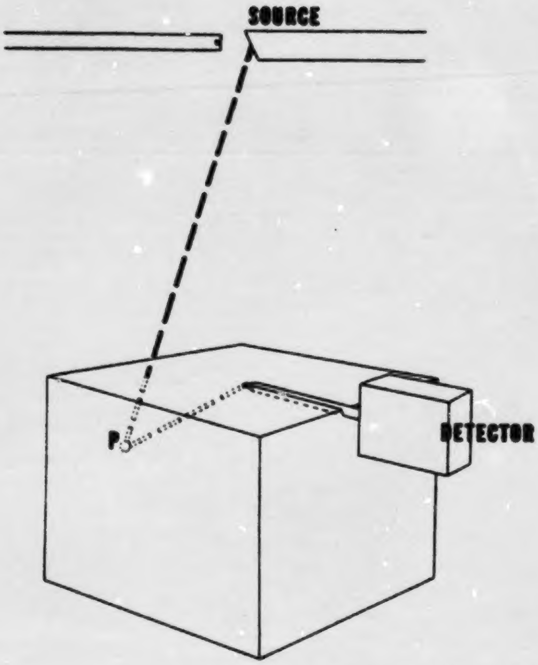

Figure 3-5. The effect of backscatter.

Assume that figure 3-3 represents a cross-section of a patient lying on a treatment table. The focal spot-to-skin distance (FSD), also called the source to skin distance (SSD), is 50 cm. Using the available information provided by the measured half-value layer and air dose rate, it is necessary to determine the radiation dose to be delivered to: (1) the skin, (2) the tumor lying at a certain depth beneath the skin, and (3) nearby organs lying above or below the tumor. To make the necessary measurements, let us replace the patient in figure 3-3 with a phantom, as seen in figure 3-4.

Effect of backscatter on surface dose rate. The *surface dose rate*, in effect, is the same as the skin dose. Assume that the surface dose rate of our phantom measures 81 R/min at 50 cm from the tube, as shown in figure 3-4. This reading is 21 R/min above the air dose rate of 60 R/min which we measured earlier. How can this difference be explained?

The difference is due to *backscattering* of photons from Compton interactions occurring in the phantom. Figure 3-5 shows a photon from the primary beam not falling on the detector probe (hence, would not be registered in an air dose reading) but interacting by Compton scattering at point P, after which the scattered photon is redirected toward the meter probe. Multiple scatterings of this type are responsible for the increased reading of 81 R/min at the surface from the 60 R/min air dose rate.

The *backscatter factor* is expressed as the ratio of the surface dose rate to the air dose rate as follows:

$$\text{Backscatter factor} = \frac{\text{surface dose rate}}{\text{air dose rate}}$$

In this case

$$\text{Backscatter factor} = \frac{81}{60} = 1.35$$

Normally, charts are accomplished showing the backscatter factor for therapy beams with different half-value layers and treatment areas. (The next text segment explains the effect of these two factors on the backscatter factor.) To determine the surface dose (skin dose) rate from such a chart, simply use the following formula:

Surface dose rate = backscatter factor X air dose rate

Exercises (821):

1. How does the backscattering of therapy beam photons affect the surface dose rate?

2. What is the backscatter factor?

3. What is the dose rate to the patient's skin for each of the two following therapy beams?
   (1) Half-value layer 1.2 mm Cu, 10 x 10 cm treatment field, air dose rate 65 R/min, backscatter factor 0.90.
   (2) Half-value layer 1 mm Cu, 8 x 8 cm treatment field, air dose rate 45 R/min, backscatter factor 0.75.

822. Indicate how beam quality and field size affect backscatter.

Effect of beam quality on backscatter. The backscatter is not always 1.35 but varies as certain conditions change. The amount of

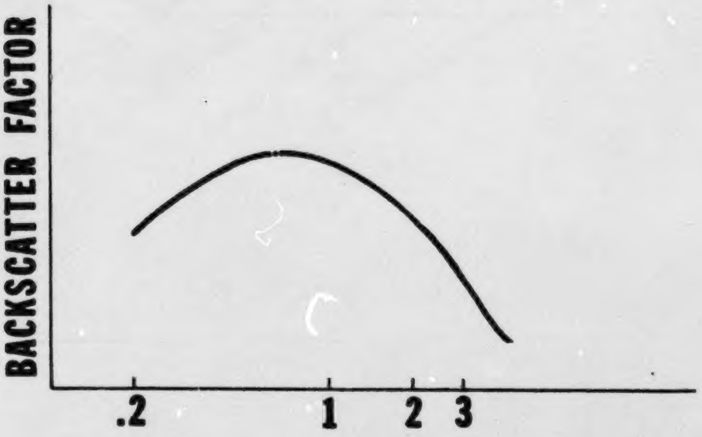

Figure 3-6. Relationship between the backscatter factor and beam quality for a 10 x 10 cm treatment field.

backscatter present depends on the quality of the beam, which, in turn, affects depth of penetration and the scattering angle probability. Notice in figure 3-6 that penetration of low energy beams into the phantom minimizes the backscatter factor—or put another way, the limited penetration reduces the amount of scatter redirected toward the measuring probe. Consequently, the backscatter factor is low. As the half-value layer increases, the backscatter factor also increases because the deeper penetration of

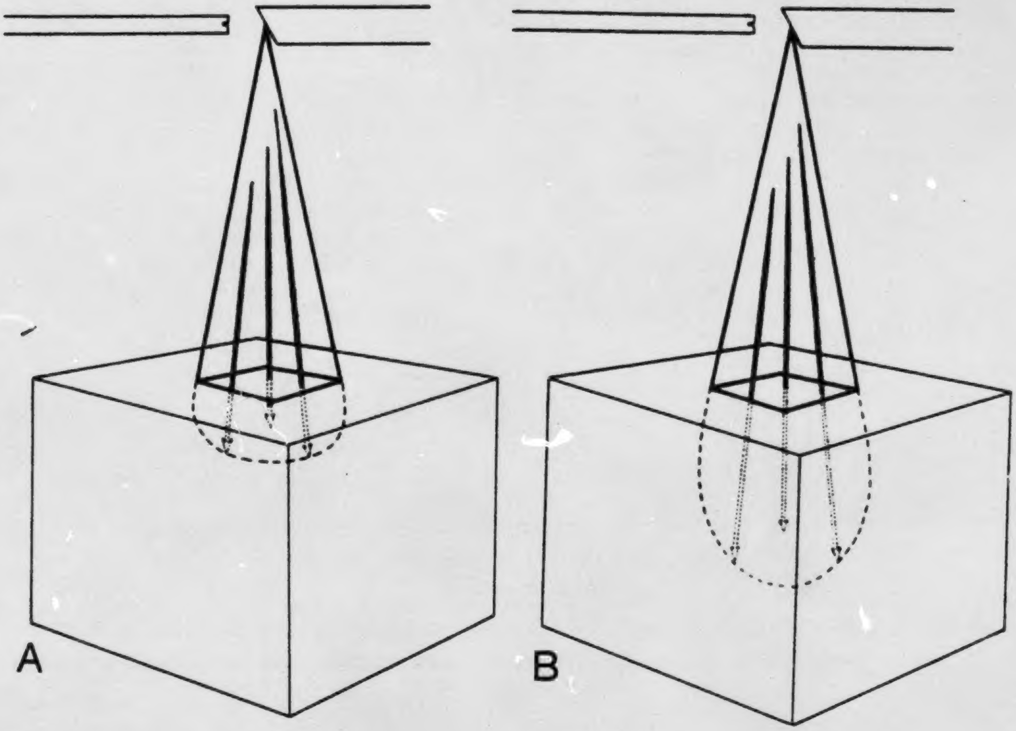

Figure 3-7. Relationship between beam quality and volume of scatter. A—Low quality beam with small scatter volume. B—High quality beam with large scatter volume.

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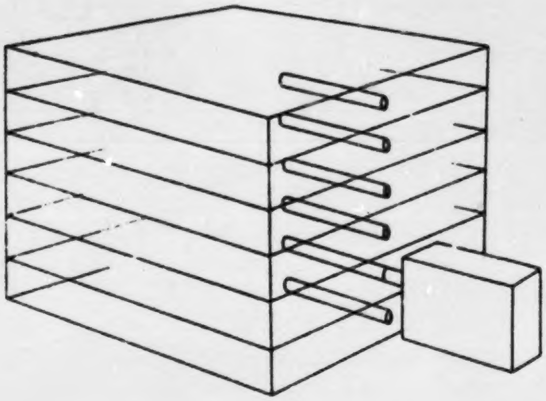

Figure 3-8. Depth dose measurements in a phantom.

the beam gives a larger effective volume of scatter. (See fig. 3-7.) Notice again in figure 3-6 that with a half-value layer of approximately 1 mm of Cu, a maximum is reached. If the half-value layer is increased beyond this point, the backscatter is reduced. The reduction is due to the scattering angle at the higher half-value layers which occur predominantly in a forward direction. Consequently, many of the scattered photons are not redirected back toward the meter probe.

Effect of field size on backscatter. As explained in the preceding paragraph, backscatter is increased as the effective scattering volume is increased. Similarly, the backscatter is increased as the size of treatment field is increased. For example, a 10 x 10 inch field produces more backscatter than an 8 x 8 inch field if all other factors are equal.

Exercises (822):

Fill in each blank space with one appropriate word.

1. The quality of the therapy beam affects backscatter due to the depth of ___________ and scattering ___________ .
2. The larger the ____________ of radiated material, the greater the ___________ .
3. Beams with a high half-value layer produce a low backscatter factor because the photons scatter mostly in a ___________ direction.
4. A large treatment field produces more ___________ than a small one.

823. Given the necessary data, find the percentage-depth dose and total dose at various depths in tissue.

Calculations of depth dose. Dose rates at various depths in tissue are calculated in a manner similar to the way we arrived at surface dose rates. Dose rate readings are taken at various depths in a tissue-equivalent phantom, as illustrated in figure 3-8.

TABLE 3-1
PERCENTAGE DEPTH DOSES FOR A 10 x 10 CM TREATMENT FIELD AND A BEAM HALF-VALUE LAYER OF 1 MM CU AND FSD OF 50 CM

Depth in Phantom (in cm)	Meter Reading (R/min)	Percentage Depth Dose (%)
0 (surface)	81	100
2	76	94
4	62.5	77
6	48	59
8	36.5	45
10	27	33
12	19.5	24
14	14.5	18

TABLE 3-2

PERCENTAGE DEPTH DOSES FOR FIELDS OF VARIOUS SIZES USING A BEAM HALF-VALUE LAYER OF 1 MM CU AND A FSD OF 50 CM

Depth (in cm) \ Field Size (in cm^2)	20	50	100	200	400
0	100	100	100	100	100
2	83	90	94	97	98
4	62	71	77	82	86
6	44	52	59	65	70
8	31	38	45	50	55
10	22	28	33	38	44
12	15	20	24	29	34
14	11	14	18	22	26

If a dose of 81 R/min delivered to the surface is expressed as a 100 percent dose, then the dose delivered to specific depths of tissue may be expressed as a percentage of the surface dose rate, commonly referred to as the *percentage-depth dose.* The percentage-depth dose is defined as the ratio of the dose rate at a given depth to the dose rate at the surface.

Let's assume that we take a reading at 2 cm below the surface in our phantom and find it to be 76 R/min. The percentage-depth dose at 2 cm then becomes

$$\begin{aligned} \text{percentage-depth dose} &= \frac{\text{dose rate at depth}}{\text{surface dose rate}} \\ &= \frac{76}{81} \\ &= .94 \end{aligned}$$

Commonly expressed as a percentage, this value becomes a percentage-depth dose of 94 percent. Thus, with a surface dose rate of 81 R/min, the *tumor* dose rate 2 cm below the skin is 76 R/min since 81 x .94 = 76.

In actual practice, percentage-depth doses once calculated are combined and listed, such as those shown in tables 3-1 and 3-2. From this point, to find the *total* dose to a tumor or to an organ above or below the tumor, simply multiply the tumor dose rate by the time of exposure. Using our example once again, if the exposure is 5 minutes in duration, the total tumor dose is 380 R since 76 x 5 = 380.

Exercises (823):

1. What is the percentage-depth dose at a depth of 14 cm if the dose rate at 14 cm is 55 R/min and the surface dose rate is 63 R/min?

Complete the following exercises by referring to table 3-2:

2. Using a 10-minute exposure with a surface-dose rate of 40 R/min, what is the total dose to a tumor at a depth of 6 cm if the treatment field is 10 x 10 cm?

3. Using the information in exercise #2 above, what is the total dose to an organ lying 2 cm above the tumor?

4. Using a 9-minute exposure with a surface-dose rate of 61 R/min, what is the total dose to a tumor at a depth of 12 cm if the treatment field is 20 x 20 cm?

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MODIFICATIONS

Pages 37-74 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:
800 - 1. c.
800 - 2. b, c.
800 - 3. a, c.
800 - 4. a.
800 - 5. b.
800 - 6. b.
800 - 7. a.
800 - 8. c.
800 - 9. a.
800 - 10. a.

801 - 1. Body, origin, and insertion.
801 - 2. The proximal point of attachment located on the more fixed structure.
The distal point of attachment located on the more movable structure.
801 - 3. It has two—the supraglenoid tuberosity and the coracoid process.
The radial tuberosity.
801 - 4. Heads.

802 - 1. F. It is called an antagonistic muscle group.
802 - 2. T.
802 - 3. T.
802 - 4. F. It supports a prime mover.
802 - 5. T.
802 - 6. F. It is an agonistic muscle.
802 - 7. T.

803 - 1. g.
803 - 2. d.
803 - 3. c, d.
803 - 4. e.
803 - 5. b.
803 - 6. f.
803 - 7. c.
803 - 8. d.
803 - 9. g.
803 - 10. f.
803 - 11. e.
803 - 12. g.
803 - 13. f, g.
803 - 14. e, f.
803 - 15. b.
803 - 16. c, d.

804 - 1. c.
804 - 2. f.
804 - 3. f.
804 - 4. c.
804 - 5. a.
804 - 6. b.
804 - 7. d.
804 - 8. c.
804 - 9. a, b, c, e, g.
804 - 10. d, f.
804 - 11. a.
804 - 12. c.

805 - 1. lucidum.
805 - 2. deeper (internal).
805 - 3. root.
805 - 4. follicle.
805 - 5. dermis; subcutaneous.
805 - 6. sebum; lubricates.

806 - 1. i.
806 - 2. g.
806 - 3. e.
806 - 4. d.
806 - 5. a.
806 - 6. a.
806 - 7. c.
806 - 8. e.
806 - 9. g.
806 - 10. h.
806 - 11. d.
806 - 12. b.
806 - 13. i.
806 - 14. b.

CHAPTER 2

Reference:
807 - 1. Six.
807 - 2. Place it exactly where it will be used, with the front side of the container about one foot short of where you want the front of the assembled table. Identify the front side of the table by noting the shape of the container cover.
807 - 3. The tabletop.
807 - 4. The container cover.
807 - 5. Attached to the inside of the tabletop.
807 - 6. Bucky unit and foot and head end supports.
807 - 7. Do not lower the support until it is counterbalanced by adding the swivel arm, X-ray tube, etc. Before disassembling the unit, raise the support to the top of the vertical mast before removing the swivel arm, etc.
807 - 8. 15 mA X-ray apparatus and 50/100 mA X-ray apparatus.
807 - 9. On the inside of the container cover.

808 - 1. T.
808 - 2. T.
808 - 3. F. It may be used without the rectifier but cannot be used without the transformer.
808 - 4. F. They are used to connect the transformer to the X-ray tube or to the rectifier.
808 - 5. T.
808 - 6. T.
808 - 7. F. You need not maintain polarity between the two.
808 - 8. T.
808 - 9. F. You must maintain polarity between the two.
808 - 10. F. It should be connected to the combination plug of the short rectifier cable, which in turn is connected directly to the control panel.

809 - 1. Place the bottom portion of the control unit chest with the open-end-up on top of the inverted top section of the chest and fasten them together using the draw bolts.
809 - 2. (1) TUBE—Connects the control unit to the X-ray tube and collimator.
 (2) FT. SW.—Connects the control unit to the fluoroscopic foot switch.
 (3) BUCKY—Connects the control unit to the table bucky.
 (4) LINE—Connects the control unit to the main power source.
 (5) TRANS/RECT—Connects the control unit to the transformer or transformer and rectifier.

810 - 1. The generator must be properly grounded and the plug and receptacle must be in good repair.
810 - 2. (1) By connecting the "pigtail" to a generator grounding rod. (2) By connecting the "pigtail" to another grounding rod (3 feet long) inserted at least 2½ feet into the ground near the connection between the two power cables.

811 - 1. 250. If it is set lower than the incoming line voltage, some of the control unit circuits may be damaged.
811 - 2. Immediately turn the main switch OFF and set the line adjuster to 250.
811 - 3. Depress and hold the line check switch and turn the line adjuster until the kilovolt meter reads in the red area.

812 - 1. (1) Anode characteristics (stationary or rotating).
 (2) Rectification (self- or full-wave).
 (3) Focal spot size (large or small focus).
812 - 2. 30 mA—90 kVp, if self-rectified; and 58 mA—90 kVp, if full-wave rectified (if you are using the rectifier).
812 - 3. To prevent an excessive voltage drop across the X-ray tube.
812 - 4. Make an exposure and read the voltage indicated on the kilovolt meter during exposure. Subtract that amount from the preset voltage.
812 - 5. Your mA is too high for the existing conditions.

813 - 1. The mA should not be operated in those areas.
813 - 2. Under load (during exposure).
813 - 3. It activates the filament scale.
813 - 4. (1) Turn the mA selector fully counterclockwise.
 (2) Set the radiographic timer at 3 to 4 seconds.
 (3) While making an exposure, turn the mA adjuster clockwise until the mA (top scale) reads 25.
 (4) After the exposure ends, depress and hold the filament check switch and read the value on the filament scale.
813 - 5. Repeat the procedure indicated in exercise #4 (above), finding the filament scale values for various mA readings. Record the information.
813 - 6. (1) Depress and hold the filament check switch.
 (2) Turn the mA adjuster until the needle on the filament scale reads 6.5.
 (3) Release the filament check switch.

814 - 1. 1001, 3000X, and TLX.
814 - 2. 1001—10 seconds; 3000X—60 seconds; TLX—45 seconds.
814 - 3. 1001—by reflected light.
 3000X—by reflected light.
 TLX—by reflected or transmitted light.
814 - 4. Increase the mAs.
814 - 5. Use low kVp as long as adequate penetration and density are not sacrificed.

CHAPTER 3

Reference:
815 - 1. The differential response in cells to radiation—abnormal cells are more sensitive to radiation than normal cells.
815 - 2. To damage or control the growth of abnormal cells and to spare the surrounding normal cells.

816 - 1. a, b.
816 - 2. b.
816 - 3. b.
816 - 4. a.
816 - 5. b.
816 - 6. b.
816 - 7. b.
816 - 8. a, b.

817 - 1. (1) Sensitivity of the tumor tissue. Treatment of radiosensitive tumors is more successful than treatment of radioresistant tumors.
 (2) Stage of tumor development when treatment is initiated. Early treatment improves the chance for success.
817 - 2. Treatment aimed at curing the patient.
817 - 3. When he remains alive for 5 years after treatment with no evidence of the disease.
817 - 4. Symptomatic treatment of a patient whose condition cannot be cured.

818 - 1. Correct.
818 - 2. Incorrect. The characteristic radiation emitted by the copper may have sufficient energy to reach the patient, thereby increasing his skin dose but not substantially aiding in the treatment.
818 - 3. Correct.

819 - 1. Half-value layer. The thickness of a material that reduces the beam intensity to one-half its original value.

819 - 2. The output of different machines varies even at the same kVp values.

819 - 3. (1) 0.75 mm Cu.
(2) 0.50 mm Cu.

820 - 1. 59 R/min. Explanation:

$$I_2 = \frac{(I_1)(D_1)^2}{(D_2)^2} = \frac{(85)(2500)}{3600} = \frac{212500}{3600} = 59$$

820 - 2. 173.5 R/min. Explanation:

$$I_2 = \frac{(I_1)(D_1)^2}{(D_2)^2} = \frac{(85)(2500)}{1225} = \frac{212500}{1225} = 173.5$$

821 - 1. It increases the rate.

821 - 2. The ratio of the surface dose rate to the air dose rate.

821 - 3. (1) 58.5 R/min.
(2) 33.7 R/min.

822 - 1. penetration; angle.
822 - 2. volume; backscatter.
822 - 3. forward.
822 - 4. backscatter.

823 - 1. 87 percent. Explanation:

$$\text{percentage depth dose} = \frac{55}{63} = .87$$

823 - 2. 236 R. Explanation:

tumor dose rate = 40 × .59
= 23.6
total tumor dose = 23.6 × 10
= 236

823 - 3. 308 R. Explanation:

organ dose rate = 40 × .77
= 30.8
total organ dose = 30.8 × 10
= 308

823 - 4. 212.2 R. Explanation:

tumor dose rate = 61 × .34
= 0.7
total tumor dose = 20.7 × 9
= 186.3

MODIFICATIONS

Pages 78-80 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.

2. USE NUMBER 1 OR NUMBER 2 PENCIL.

90370 05 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

GENERAL INFORMATION AND ADMINISTRATION

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

10-5

Multiple Choice

1. (800) Which muscle tissue microscopically examined is striated, voluntarily controlled, responsible for leg movement, and comprises about 80 pounds of weight for a 200-pound individual?

   a. Skeletal alone.
   b. Both smooth and cardiac.
   c. Both smooth and skeletal.
   d. Both cardiac and skeletal.

2. (801) That part of a skeletal muscle located between its proximal and distal points of attachment is generally described as its

   a. insertion.
   b. origin.
   c. body.
   d. head.

3. (801) If, in human anatomy, the proximal portion of a skeletal muscle splits itself into two divisions before it attaches to a more fixed anatomical structure, each division of the muscle is sometimes referred to as

   a. a head.
   b. a body.
   c. an insertion.
   d. a distal origin.

4. (802) Which of the following muscles, at some time during extension and flexion of the elbow, perform antagonistic actions and thereby provide coordinated movements?

   a. Brachialis and the bracioradialis.
   b. Triceps brachii and the brachialis.
   c. Biceps brachii and the triceps brachii.
   d. Brachioradialis and the triceps brachii.

5. (802) During flexion of the elbow, which skeletal muscle is considered an agonist?

   a. Brachialis.
   b. Biceps brachii.
   c. Triceps brachii.
   d. Brachioradialis.

6. (802) Stabilizing muscles, located about the shoulder, contract during elbow flexion so that the elbow movement occurs in the desired direction and plane. These muscles are therefore said to be

   a. agonistic.
   b. synergistic.
   c. antagonistic.
   d. prime movers.

7. (803) Which skeletal muscle has its insertion at the proximal portion of the humerus?

   a. Deltoid.
   b. Psoas major.
   c. Pectoralis major.
   d. Quadriceps femoris.

8. (803) Which skeletal muscle has its origin in the anterior superior iliac spine?

   a. Gastrocnemius.
   b. Pectoralis major.
   c. Serratus anterior.
   d. Quadriceps femoris.

9. (803) The gastrocnemius skeletal muscle is responsible for

   a. thigh flexion.
   b. plantar flexion of the foot.
   c. rotation of the scapula.
   d. flexion or extension of the arm.

10. (804) The principal layers of the skin (outer and inner) are correctly named the

    a. dermis and the epidermis.
    b. papillary and the reticular.
    c. stratum basale and the stratum corneum.
    d. stratum granulosum and the stratum spinosum.

11. (804) The stratum granulosum is composed of two or three rows of flattened cells and is located, in relation to other structural sublayers of the skin, between the

    a. epidermis and the dermis.
    b. second and the third layers of the epidermis.
    c. stratum lucidum and the stratum spinosum of the epidermis.
    d. deepest layer of the epidermis and the papillary layer of the dermis.

12. (804) Which sublayer of the dermis is located directly beneath the deepest layer of the epidermis?

    a. Papillary.
    b. Reticular.
    c. Stratum lucidum.
    d. Stratum basale.

13. (804) The only sublayer which is not a part of the skin's epidermis is the

    a. stratum spinosum.
    b. stratum lucidum.
    c. stratum corneum.
    d. reticular.

14. (805) What is the name of the small muscles which insert into the hair follicles, and where do they originate?

    a. Erector; dermis.
    b. Arrector; dermis.
    c. Arrector; epidermis.
    d. Erector; sebaceous gland.

15. (805) Which glands are appendages of the skin and secrete sebum?

    a. Sweat glands.
    b. Mammary glands.
    c. Sebaceous glands.
    d. Sudoriparous glands.

16. (806) Which gland has a butterfly appearance, regulates the metabolism, and has two lobes connected by an isthmus?

    a. Thyroid.
    b. Exocrine.
    c. Endocrine.
    d. Parathyroid.

17. (806) Which of he endocrine-type glands reaches its maximum development during the early years of childhood and is responsible, in part, for the production of antibodies?

    a. Pituitary.
    b. Adrenal.
    c. Gonad.
    d. Thymus.

18. (806) Which endoctrine-type gland would be responsible for a winning runner's "kick" that enables him to come from behind and break the tape?

    a. Testes.
    b. Adrenal.
    c. Pancreas.
    d. Pituitary.

19. (806) Which estrogen prepares the uterus for implantation of a fertilized ovum?

    a. Androgens.
    b. Testosterone.
    c. Androsterone.
    d. Progesterone.

20. (807) To properly lift a field radiographic table, each person grasping a handle must lift at least

    a. 66 2/3 lbs.
    b. 100 lbs.
    c. 133 1/3 lbs.
    d. 200 lbs.

21. (807) If a filed radiographic table is properly lifted, there is a total of how many persons holding a total of how many handles?

    a. Enough to easily lift 400 lbs.
    b. Three persons lifting 6 handles.
    c. Four persons lifting 8 handles.
    d. Six persons lifting 6 handles.

22. (807) The manufacturer's instructions for assembling the field radiographic table are located on the

    a. swivel arm.
    b. tabletop's underside.
    c. inside of the container cover.
    d. outside of the container cover.

23. (808) Field hospital personnel should never connect the power cord of the 50/100 mA X-ray apparatus to the power source until the

    a. ammeter is connected.
    b. apparatus is completely assembled.
    c. apparatus is completely disassembled.
    d. transformer oil has been drained and replaced.

24. (808) Under no circumstances can the 50/100 mA X-ray be used without connecting

    a. the rectifier.
    b. the transformer.
    c. both the rectifier and the power cord.
    d. both the transformer and the rectifier.

25. (808) If you desire to double the 50/100 mA X-ray apparatus' capacity, you should electrically reconnect the circuit to include the

    a. rectifier.
    b. X-ray tube.
    c. transformer.
    d. control unit.

26. (808) In making the electrical connections of the 50/100 mA X-ray apparatus, it is not of prime importance that correct polarity be established between the

    a. X-ray tube and the transformer or rectifier.
    b. transformer and the X-ray tube.
    c. rectifier and the transformer.
    d. rectifier and the X-ray tube.

27. (809) The purpose of the middle receptacle on the back of the control-unit stand is to connect the control unit with the

    a. main power source.
    b. fluoroscopic floor switch.
    c. X-ray tube and collimator.
    d. bucky of the radiographic table.

28. (809) Of the five electrical receptacles found on the back of the control unit, the one that connects the unit to the main power source is the

    a. TUBE.
    b. LINE.
    c. BUCKY.
    d. FT. SW.

29. (811) Just prior to connecting the power cord to the power supply, it is imperative to set the line adjuster of the 50/100 mA X-ray apparatus to

    a. maximum.
    b. minimum.
    c. any setting low enough to cause a buzzer to sound.
    d. either 110 volts or 220 volts.

30. (811) The line adjuster is purposely turned to the highest setting prior to activating the 50/100 mA X-ray apparatus to

    a. reduce the voltage setting to a minimum value.
    b. check the operation of a buzzer circuit.
    c. prevent certain injury to personnel.
    d. prevent possible damage to equipment.

31. (812) Before you can ascertain the voltage drop across the X-ray tube during 50/100 mA apparatus operation, you must also know the

    a. present voltage reading.
    b. amount of amperes being used.
    c. location of a table of logarithms.
    d. location of the manufacturer's instructions.

32. (812) The voltage drop across the X-ray tube during 50/100 mA apparatus operation is determined by the process of

    a. subtraction.
    b. multiplication.
    c. logarithmic calculation.
    d. instrumental readout without calculation.

33. (812) As a general rule, if the difference between the actual tube voltage read on the control-unit voltmeter of the 50/100 mA apparatus during exposure and the preset voltage exceeds 5 kVp, the

    a. "red-line" values were wrong.
    b. voltage applied was improper.
    c. mA was too high for existing conditions.
    d. technique selector was on the wrong setting.

34. (813) If the 50/100 mA apparatus is being used for fluoroscopic purposes, the mA meter on the control panel should be read

    a. before the power switch is closed and the fuse inserted.
    b. before the filament-check switch is closed.
    c. on the top scale.
    d. on the bottom scale.

35. (813) The red zones on the mA meter of the 50/100 mA unit control panel signify that the

    a. mA should not be operated in red areas.
    b. voltage drop across the tube is excessive.
    c. instrument has not been "red-lined" properly.
    d. applied voltage is so high that excessive current has melted the ammeter shunt.

36. (813) The mA meter on the 50/100 mA unit control panel reads the mA only when the

a. unit is overloaded.
b. unit is under load.
c. applied MAs is in the red-zone areas.
d. mA adjuster is being used and the filament check switch is simultaneously closed.

37. (813) Assume you have set up the 50/100 mA apparatus in the field and properly prepared a filament chart, as follows:

Filament Scale	mA
3.5	25
5.5	40
6.5	50

You desire to use a 40 mA for a radiograph. Which of the following steps do you perform first?

a. Turn the mA adjuster until the needle on the filament scale reads 5.5.
b. Set the radiographic timer to 5 1/2 seconds.
c. Depress and hold the filament check switch.
d. Release the filament check switch.

38. (814) Which, if any, of the three currently available types of Polaroid special film requires the least amount of time for processing?

a. 3000X.
b. 1001.
c. TLX.
d. They all are processed for equal lengths of time.

39. (814) After processing a polarized radiograph, it definitely appears too dark. What change should you make in 50/100 mA apparatus in the field to correct the exposure on subsequent radiographs?

a. Decrease the applied voltage.
b. Increase the processing time.
c. Decrease the mAs.
d. Increase the mAs.

40. (814) To increase the contrast on a Polaroid radiograph, along with certain other considerations, you should use

a. low kVp.
b. high mAs.
c. high kVp.
d. low mAs.

41. (816) All the statements concerning benign tumors are true except they

a. can become dangerous.
b. usually are treated with radiation.
c. usually are enclosed in capsules.
d. exist only in the immediate site of growth and can be removed by surgery.

42. (817) Radical treatment of a tumor means that

a. the tumor is radioresistant.
b. the patient's cure is considered improbable.
c. an attempt is made to cure the patient.
d. the patient will experience 5 years of no further trouble.

43. (817) Palliative treatment for a tumor is not expected to

a. significantly reduce pain.
b. enhance some basic function.
c. effect a cure lasting 5 years or more.
d. be orientated toward the patient's symptoms.

44. (818) You are to perform tumor therapy using a combination filter composed of tin, copper, and aluminum. The safest metal to place nearest to the patient's skin is

a. aluminum, because of its porosity.
b. aluminum, because of its atomic weight.
c. tin, because of its malleability and flexibility.
d. copper, because of its atomic number and conductivity.

45. (818) You are to perform tumor therapy using a Thoraeus filter. The order in which they should be placed near the tube to reduce patient skin dosage is

a. tin and aluminum.
b. copper and aluminum.
c. aluminum, copper, and tin.
d. tin, copper, and aluminum.

46. (819) In regard to the quality of a therapy beam, its "half-value layer" expresses the beam's

a. absorption rate.
b. absolute effect.
c. ability to penetrate.
d. filtration capability.

47. (819) Given the following data. Beam: 15 mA, 200 kVp, 80 R/min at 50 cm using a Thoraeus filter with these results:

60 R/min at 50 cm, with 0.25 mm Cu added.
50 R/min at 50 cm, with 0.50 mm Cu added.
40 R/min at 50 cm, with 0.75 Cu added.

What is the beam's quality, measured in half-wave layer?

a. 0.75 mm Cu.
b. 0.50 mm Cu.
c. 0.375 mm Cu.
d. 0.25 mm Cu.

48. (819) If a beam were produced with 15 mA, 200 kVp, 50 R/min at 50 cm, using a Thoraeus filter, what would be the half-value layer, using the following data:

40 R/min at 50 cm with 0.10 mm Cu added.
30 R/min at 50 cm with 0.15 mm Cu added.
25 R/min at 40 cm with 0.25 mm Cu added.
25 R/min at 50 cm with 0.30 mm Cu added.

a. 0.10 mm Cu.
b. 0.15 mm Cu.
c. 0.30 mm Cu.
d. Either 0.25 or 0.30 mm Cu.

49. (820) Using the formula $I_2 = \frac{I_1(D_1)^2}{(D_2)^2}$, if a therapy beam provides an air-dose rate of 75 R/min at 50 cm from the focal spot, what should the air-dose rate be at 25 cm?

a. 37.5 R/min.
b. 300 R/min.
c. 150 R/min.
d. 18.75 R/min.

50. If a therapy beam provides an air-dose rate of 25 R/min at 50 cm from the focal point, at what distance from the focal point will the air-dose rate be 100 R/min?

   a. 6.25 cm.
   b. 25 cm.
   c. 12.5 cm.
   d. 200 cm.

51. (820) Determine the intensity of a therapy beam at 40 cm if an initial measurement taken at a point 55 cm from the focal point of the tube indicates an air-dose rate of 65 R/min.

   a. 34.3 R/min.
   b. 89.4 R/min.
   c. 120.0 R/min.
   d. 122.9 R/min.

52. (821) If the air-dose rate and the surface-dose rate, respectively, are 86 and 50, the backscatter factor is

   a. 36.
   b. 0.58.
   c. 136.
   d. 1.92.

53. (821) If the surface-dose rate is 75 and the air-dose rate is 50, the backscatter factor is

   a. 1.5.
   b. 0.67.
   c. 125.
   d. 150.

54. (821) Determine the dose rate to the patient's skin for a therapy beam using this data: half-value layer 1.2 mm Cu, 8 x 8 cm treatment field, air-dose rate 70 R/min, backscatter factor 0.60.

   a. 420 R/min.
   b. 72.0 R/min.
   c. 38.4 R/min.
   d. 42.0 R/min.

55. (822) Beams with a high half-value layer produce a low-backscatter factor because the photons scatter mostly in what direction?

   a. Upward.
   b. Laterally.
   c. Forward.
   d. Backward.

56. (822) With other considerations being the same, what is the ratio of a therapy beam's backscatter connected with a large treatment field as compared to that of a smaller field?

   a. Decreases.
   b. Increases.
   c. Remains the same.
   d. Decreases slightly.

57. (822) As the effective scattering volume of a therapy beam is increased, its backscatter

   a. increases.
   b. decreases slightly.
   c. decreases geometrically.
   d. remains the same, in most instances.

58. (823) A phantom surface-dose rate is 91 R/min and a reading at 2 cm below the surface is found to be 76 R/min. The percentage-depth dose at 2 cm then becomes

   a. 0.15.
   b. 0.30.
   c. 0.83.
   d. 1.2.

MODIFICATIONS

Pages 9- 14 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

LIST OF CHANGES

COURSE NO.
90370

EFFECTIVE DATE OF SHIPPING LIST
17 Mar 76

CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.

1. CHANGES FOR THE TEXT: VOLUME 1

a. Page 3, col 2, line 2 from the bottom: Change "a slong" to "as long."

b. Page 10, col 1, line 6: Insert "circuit" between "series-parallel" and "find."

c. Page 26, col 1, line 9: Delete "the connection . . . and . . ."

d. Page 33, col 2, line 1: Change "25" to "125."

e. Page 36, col 2, lines 9 and 10: Change "5 1/2" to "4."

f. Page 37, col 1, line 10: Change "5 1/2" to "4." Col 2, line 5: Change "5 1/2" to "4."

g. Page 39, col 2, line 10: Add after circulator, "For this exercise disregard figure 1-48A and assume that 400,000 H. U. are dissipated from the anode every 10 minutes."

h. Page 41, col 1, line 25: Change "FFO" to "FFD." Line 41: Change "increased" to "doubled." Line 43: Change "increased" to "doubled."

i. Page 45, col 1, line 13: Add "Why?" at end of exercise 041-8.

j. Page 46, col 2, line 4: Change "mA" to "mAs."

k. Page 48, col 2, line 15: Change "7" to "4."

l. Page 50, col 1, line 20: Between "exposure" and "with" add "devices."

m. Page 56, col 1, last line: Change "more" to "less."

n. Page 88, col 2, line 20: Change "fewer photons than does" to "of the photons transmitted by." Lines 27 and 28: Change "fewer photons than does" tc "of the photons transmitted by."

o. Page 91, col 1, line 28: Add "is" after "(mAs)."

p. Page 105, col 1, line 14: Change "15" to "12."

q. Page 114, Answers for Exercises, answer 034-4: Change "No" to "Yes."

r. Page 115, Answers for Exercises, answer 044-1: Change "right" to "left."

s. Page 118, Answers for Exercises, answer 089-2: Change "100" to "101."

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2. CHANGES FOR THE TEXT: VOLUME 2

a. Page 7, col 2, line 4 from the bottom: Change "split" to "splint."

b. Page 37, col 1, line 13: Change "facil" to "facial."

c. Page 46, col 1, line 31: Change "talocaneal" to "talocalcaneal." Col 2, line 33: Delete "that."

d. Page 57, col 1, line 11: Change "formaina" to "foramina." Line 22: Change "formaina" to "foramina."

e. Page 58, col 1, line 11: Change "describ" to "describe."

f. Page 79, Answers for Exercises, answer 202-16: After "sustentaculum" add "tali."

3. CHANGES FOR THE TEXT: VOLUME 3

a. Page 4, col 2, line 22: Change "A" to "B."

b. Page 60, col 2, line 21: Change "61" to "6-1."

c. Page 84, col 2, Answers for Exercises, answer 418-1, line 5: Change "b" to "(3)." Answer 418-1, line 9: Change "c" to "b."

4. CHANGES FOR THE TEXT: VOLUME 5

a. Page 20, col 1, line 12: Before the word "cable" delete "5-." Line 15: Change "table" to "tube."

b. Page 29, col 1, line 8 from the bottom: After "therapy" add "filter is."

c. Page 69, col 2, line 5 from the bottom: Change the SSAN from "236-56-56-56" to "236-56-56-66."

d. Page 72, fig 5-6, line 1: In the space after ANATOMIC FIELD NUMBER add "40."

5. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 1

The following questions are no longer scored and need not be answered: 80, 89 and 95.

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LIST OF CHANGES

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6. **CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 2**

The following questions are no longer scored and need not be answered: 12, 39 and 45.

7. CHANGE FOR THE VOLUME REVIEW EXERCISE: VOLUME 4

Question 37 is no longer scored and need not be answered.